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MACHINERY'S DATA SHEETS

REVISED AND RE-ARRANGED IN LIBRARY FORM

No. 14

Locomotive and Railway Data

PRICE 25 CENTS

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Heating Surface of Locomotive Boiler Flues 6
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The Industrial Press, 49-55 Lafayette Street, New York
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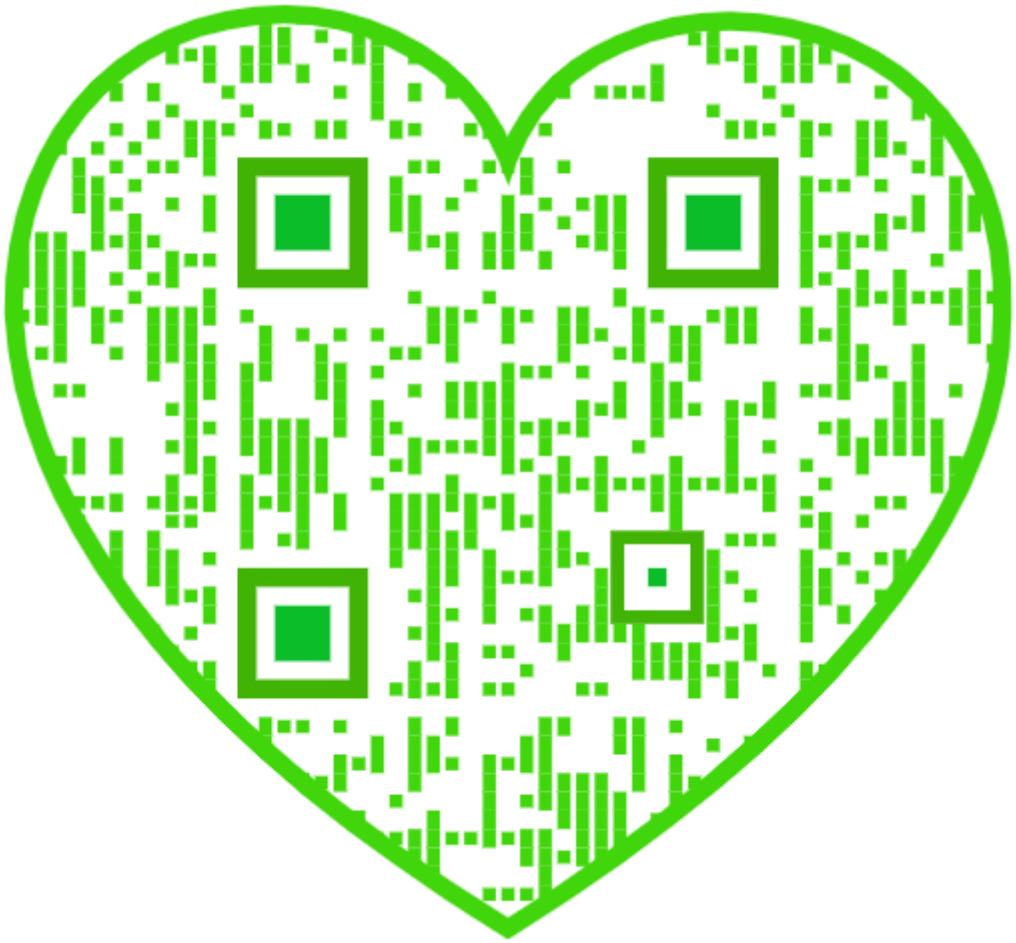

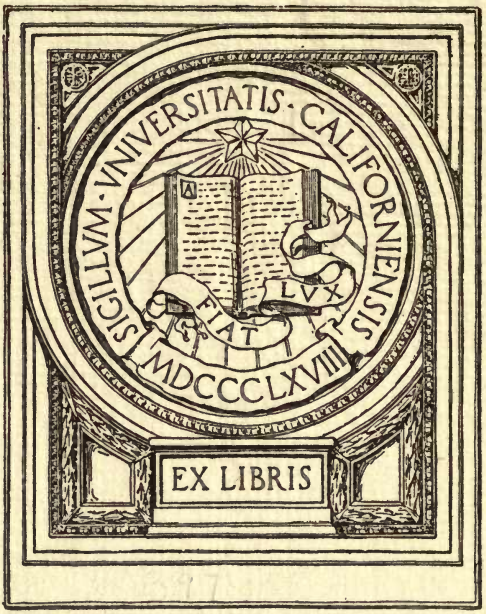
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MACHINERY'S DATA SHEET SERIES

COMPILED FROM MACHINERY'S MONTHLY DATA SHEETS AND ARRANGED WITH EXPLANATORY NOTES

No. 14

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In the following pages are compiled a number of diagrams and concise tables relating to locomotives and railway work, carefully selected from MACHINERY'S monthly Data Sheets, issued as supplements to the Engineering and Railway editions of MACHINERY since September, 1898. In order to enhance the value of the tables and diagrams, brief explanatory notes have been provided. In a note at the foot of the tables, reference is made to the page on which the explanatory note relating to the table appears.

LOCOMOTIVE AND RAILWAY DATA

Locomotive Boilers

On pages 4 and 5 are shown diagrammatical sketches of eight types of locomotive boilers, indicating, in a general way, the main features of construction. On pages 6 and 7 tables are given for determining at a glance the heating surface of locomotive boiler flues in square feet when the outside diameter and the length in feet and inches are given. Assume that it is required to find the heating surface in square feet of a flue 2 inches in diameter and 8 feet 3 11/16 inches long. From the table on page 6 we find that the heating surface of a flue of this size, 8 feet long, is 4.188 square feet. From page 7 we find that three inches of additional length adds 0.131 square foot, and 11/16 of additional length, 0.030 square foot. The total heating surface then is 4.188 + 0.131 + 0.030 = 4.349.

Bearing Pressure for Locomotive Journals

On pages 8 to 11, inclusive, are given tables of allowable bearing pressures for the different journals of various classes of locomotives. The figures on page 8 are for the engine truck journals of passenger locomotives, and are based on a pressure of 160 pounds per square inch of projected area. On page 9 are given the safe bearing pressures for the driving and trailing journals of passenger locomotives, based on a pressure of 180 pounds per square inch of projected area. The journals for freight and switching locomotives may be subjected to a pressure of 200 pounds per square inch of projected area, and the total safe allowance for journals of various sizes for locomotives of this class is tabulated on page 10. Page 11 gives the figures for tender journals, these figures being based on a pressure of 300 pounds per square inch of projected area. As an example, assume that it is required to find what would be the safe allowable total pressure on the driving wheel journals of a passenger locomotive, the diameter of the journal being 8 inches and the length 10 inches. From the table on page 9 we find, by locating the diameter in the left-hand column and the length of the journal at the top of the table, that the safe pressure per journal is 14,400 pounds.

Locomotive Classification

Several different systems are in use for indicating various classes of locomotives, the various methods used being shown on page 12. In America it is quite common to refer to the various types by the names, while in Europe the usual method is to use the Whyte system, in which the number of wheels in the pony truck, the number of driving wheels and the number of wheels in the trailing truck are indicated with figures as shown in the next last column on page 12. According to this system a 4-6-2 locomotive indicates a Pacific type passenger locomotive having a four-wheeled pony truck, six driving wheels and a two-wheeled trailing truck.

Gages of Principal Railroads of the World

On page 13 a table is given of the gages in use in various countries. The 4-foot 8 1/2-inch standard gage, it will be seen, is used practically everywhere in the leading countries, but some large systems, including that of Russia, which has a 5-foot gage, and that of India, which has a 5½-foot and a meter

(Continued on page 16.)

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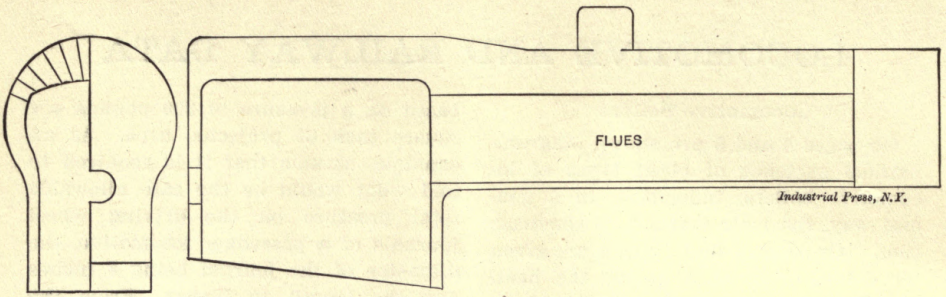
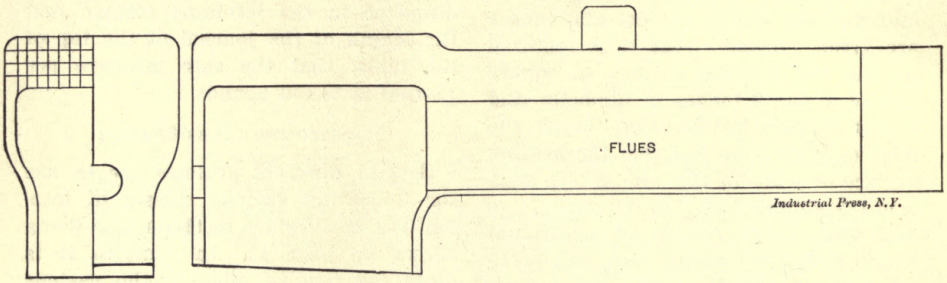
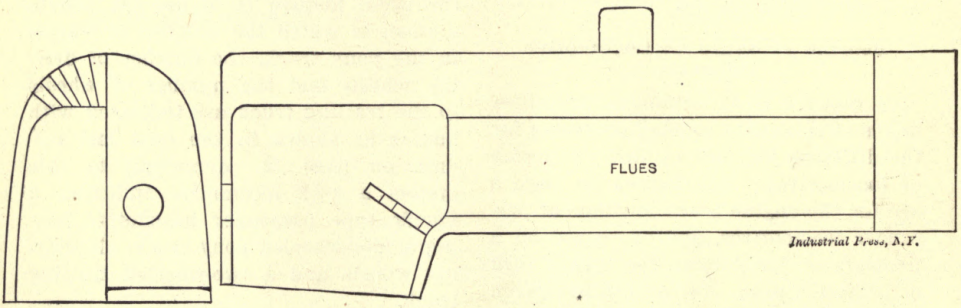
TYPES OF LOCOMOTIVE BOILERS—I



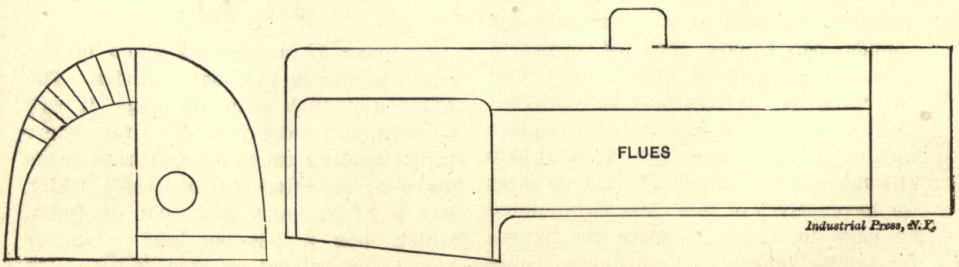
WAGON TOP.



BELPAIRE.



EXTENDED FIREBOX.



WOOTEN WIDE FIREBOX.

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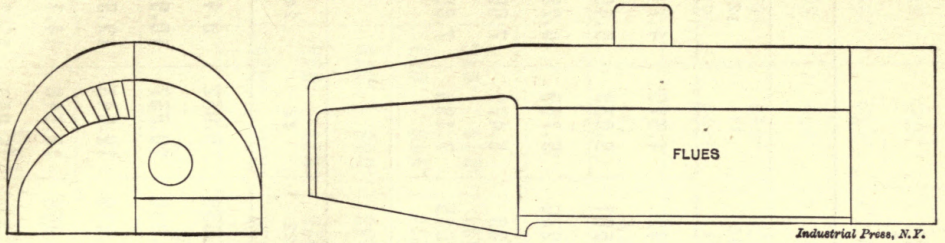
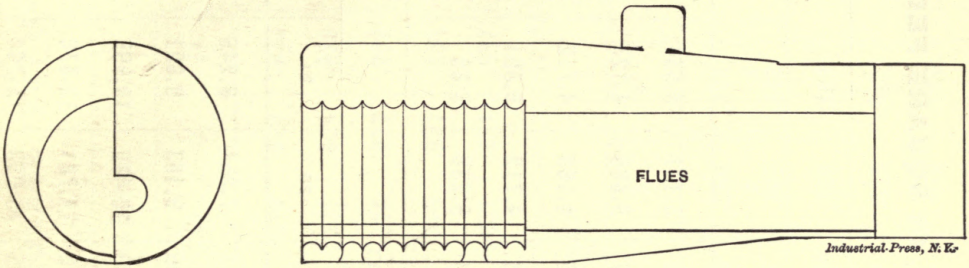
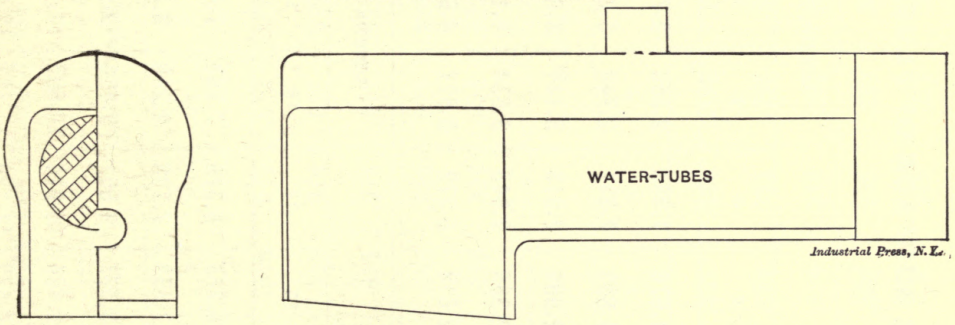
TYPES OF LOCOMOTIVE BOILERS—II



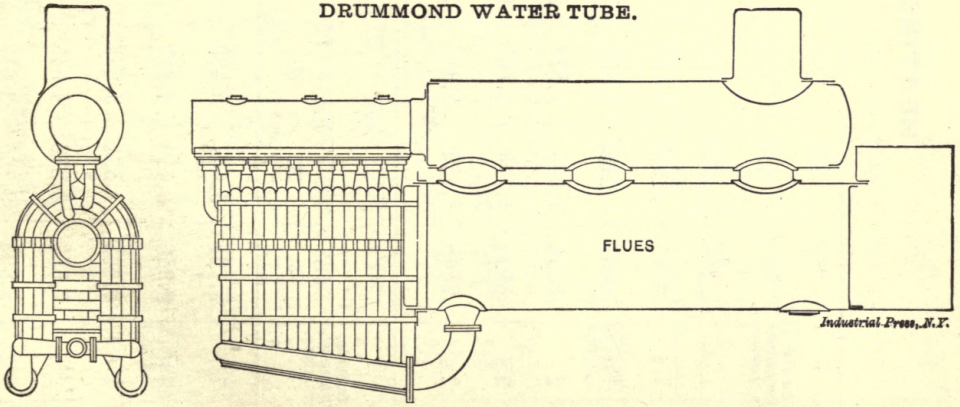
WOOTEN LOW CROWN.



LENTZ OR VANDERBILT.



DRUMMOND WATER TUBE.



BROTAN.

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HEATING SURFACE OF FLUES, IN SQUARE FEET.

Outside Diameter in Inches.	LENGTH, FEET.											
	1	2	3	4	5	6	7	8	9	10	11	12
1½	.3927	.7854	1.178	1.570	1.963	2.356	2.748	3.141	3.534	3.92	4.319	4.712
1¾	.4582	.9163	1.374	1.832	2.291	2.748	3.207	3.665	4.123	4.581	5.039	5.497
2	.5236	1.047	1.571	2.094	2.618	3.141	3.665	4.188	4.712	5.236	5.759	6.283
2¼	.5891	1.178	1.767	2.356	2.945	3.534	4.123	4.712	5.301	5.89	6.479	7.068
2½	.6545	1.309	1.963	2.618	3.272	3.927	4.581	5.236	5.89	6.545	7.199	7.854

Outside Diameter, in Inches.	LENGTH, FEET.											
	13	14	15	16	17	18	19	20	21	22	23	24
1½	5.105	5.497	5.890	6.283	6.675	7.068	7.461	7.854	8.246	8.639	9.032	9.424
1¾	5.956	6.414	6.872	7.330	7.788	8.246	8.705	9.163	9.621	10.080	10.537	10.996
2	6.806	7.330	7.854	8.377	8.901	9.424	9.948	10.472	10.995	11.519	12.043	12.566
2¼	7.657	8.246	8.835	9.424	10.014	10.603	11.192	11.781	12.370	12.959	13.548	14.137
2½	8.508	9.163	9.817	10.472	11.126	11.781	12.435	13.090	13.744	14.398	15.053	15.708

HEATING SURFACE OF FLUES, IN SQUARE FEET (Continued).

Outside Diameter, in Inches.	LENGTH, FRACTIONS OF AN INCH.														
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
1½	.002	.004	.006	.008	.010	.012	.014	.016	.018	.020	.022	.024	.026	.028	.031
1¾	.002	.005	.007	.009	.012	.014	.017	.019	.021	.024	.026	.028	.031	.033	.036
2	.003	.005	.008	.011	.013	.016	.019	.022	.024	.027	.030	.033	.035	.038	.041
2¼	.003	.006	.009	.012	.015	.018	.021	.024	.028	.031	.034	.037	.040	.043	.046
2½	.003	.007	.010	.014	.017	.020	.024	.027	.031	.034	.037	.041	.044	.048	.051

Outside Diameter, in Inches.	LENGTH, INCHES.											
	1	2	3	4	5	6	7	8	9	10	11	12
1½	.033	.065	.097	.131	.164	.196	.229	.260	.294	.327	.360	.392
1¾	.038	.076	.114	.152	.191	.229	.267	.305	.342	.382	.418	.458
2	.044	.087	.131	.174	.218	.262	.305	.349	.392	.436	.479	.523
2¼	.049	.098	.147	.196	.245	.294	.343	.393	.442	.491	.539	.589
2½	.054	.119	.163	.218	.272	.327	.381	.436	.490	.540	.599	.654

Contributed by B. J. Sinne, MACHINERY'S Data Sheet No. 12 (Railway Edition). Explanatory note: Page 3.

BEARING PRESSURE FOR LOCOMOTIVE JOURNALS.

Based on Pressure of 160 Pounds per Square Inch of Projected Area. These Figures show the Safe Allowance for Engine Truck Journals of Passenger Locomotives.

Diameter of Journal.	LENGTH OF JOURNAL.														
	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″	12″	13″	14″	15″	16″
2″	640	960	1280	1600	1920	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2¼″	720	1080	1440	1800	2160	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2½″	800	1200	1600	2000	2400	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2¾″	880	1320	1760	2200	2640	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3″	.....	1440	1920	2400	2880	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3¼″	.....	1560	2080	2600	3120	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3½″	.....	1680	2240	2800	3360	3920	4480	.....	.....	.....	.....	.....	.....	.....	.....
3¾″	.....	.....	2400	3000	3600	4200	4800	.....	.....	.....	.....	.....	.....	.....	.....
4″	.....	.....	2560	3200	3840	4480	5120	.....	.....	.....	.....	.....	.....	.....	.....
4¼″	.....	.....	2720	3400	4080	4760	5440	6120	6800	.....	.....	.....	.....	.....	.....
4½″	.....	.....	2880	3600	4320	5040	5760	6480	7200	.....	.....	.....	.....	.....	.....
4¾″	.....	.....	3040	3800	4560	5320	6080	6840	7600	.....	.....	.....	.....	.....	.....
5″	.....	.....	.....	4000	4800	5600	6400	7200	8000	8800	9600	.....	.....	.....	.....
5½″	.....	.....	.....	.....	.....	6160	7040	7920	8800	9680	10560	.....	.....	.....	.....
6″	.....	.....	.....	.....	.....	6720	7680	8640	9600	10560	11520	12480	.....	.....	.....
6½″	.....	.....	.....	.....	.....	7280	8320	9360	10400	11440	12480	13520	.....	.....	.....
7″	.....	.....	.....	.....	.....	7840	8960	10080	11200	12320	13440	14560	15680	.....	.....
7½″	.....	.....	.....	.....	.....	8400	9600	10800	12000	13200	14400	15600	16800	.....	.....
8″	.....	.....	.....	.....	.....	.....	10240	11520	12800	14080	15360	16640	17920	19200	20480
8½″	.....	.....	.....	.....	.....	.....	10880	12240	13600	14960	16320	17680	19040	20400	21760
9″	.....	.....	.....	.....	.....	.....	.....	12960	14400	15840	17280	18720	20160	21600	23040
9½″	.....	.....	.....	.....	.....	.....	.....	13680	15200	16720	18240	19760	21280	22800	24320
10″	.....	.....	.....	.....	.....	.....	.....	.....	16000	17600	19200	20800	22400	24000	25600
10½″	.....	.....	.....	.....	.....	.....	.....	.....	16800	18480	20160	21840	23520	25200	26880
11″	.....	.....	.....	.....	.....	.....	.....	.....	.....	19360	21120	22880	24640	26400	28160

BEARING PRESSURE FOR LOCOMOTIVE JOURNALS.

Based on Pressure of 180 Pounds per Square Inch of Projected Area. These Figures show the Safe Allowance for Driving and Trailing Journals of Passenger Locomotives.

Diameter of Journal.	LENGTH OF JOURNAL.														
	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″	12″	13″	14″	15″	16″
2″	720	1080	1440	1800	2160	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2¼″	810	1215	1620	2025	2430	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2½″	900	1350	1800	2250	2700	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2¾″	990	1485	1980	2475	2970	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3″	.....	1620	2160	2700	3240	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3¼″	.....	1755	2340	2925	3510	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3½″	.....	1890	2520	3150	3780	4410	5040	.....	.....	.....	.....	.....	.....	.....	.....
3¾″	.....	.....	2700	3375	4050	4725	5400	.....	.....	.....	.....	.....	.....	.....	.....
4″	.....	.....	2880	3600	4320	5040	5760	6480	.....	.....	.....	.....	.....	.....	.....
4¼″	.....	.....	3060	3825	4590	5355	6120	6885	.....	.....	.....	.....	.....	.....	.....
4½″	.....	.....	3240	4050	4860	5670	6480	7290	8100	.....	.....	.....	.....	.....	.....
4¾″	.....	.....	3420	4275	5130	5985	6840	7695	8550	.....	.....	.....	.....	.....	.....
5″	.....	.....	.....	4500	5400	6300	7200	8100	9000	9900	10800	.....	.....	.....	.....
5½″	.....	.....	.....	.....	5940	6930	7920	8910	9900	10890	11880	.....	.....	.....	.....
6″	.....	.....	.....	.....	.....	7560	8640	9720	10800	11880	12960	.....	.....	.....	.....
6½″	.....	.....	.....	.....	.....	8190	9360	10530	11700	12870	14040	.....	.....	.....	.....
7″	.....	.....	.....	.....	.....	8820	10800	11340	12600	13860	15120	.....	.....	.....	.....
7½″	.....	.....	.....	.....	.....	9450	10800	12150	13500	14850	16200	.....	.....	.....	.....
8″	.....	.....	.....	.....	.....	.....	11520	12960	14400	15840	17280	.....	.....	.....	.....
8½″	.....	.....	.....	.....	.....	.....	12240	13770	15300	16830	18360	.....	.....	.....	.....
9″	.....	.....	.....	.....	.....	.....	12960	14580	16200	17820	19440	.....	.....	.....	.....
9½″	.....	.....	.....	.....	.....	.....	.....	15390	17100	18810	20520	22230	.....	.....	.....
10″	.....	.....	.....	.....	.....	.....	.....	.....	18000	19800	21600	23400	25200	27000	28800
10½″	.....	.....	.....	.....	.....	.....	.....	.....	18900	20790	22680	24570	26460	28350	30240
11″	.....	.....	.....	.....	.....	.....	.....	.....	19800	21780	23760	25740	27720	29700	31680

Contributed by B. J. Sinne, MACHINERY'S Data Sheet No. 18 (Railway Edition). Explanatory note: Page 3.

BEARING PRESSURES FOR LOCOMOTIVE JOURNALS.

Based on Pressure of 200 Pounds per Square Inch of Projected Area. These Figures show the Safe Allowance for Driving, Engine Truck and Trailing Journals of Freight Locomotives and Switching Locomotives.

Diameter of Journal.	LENGTH OF JOURNAL.														
	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″	12″	13″	14″	15″	16″
2″	800	1200	1600	2000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2¼″	900	1350	1800	2250	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2½″	1000	1500	2000	2500	3000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2¾″	1100	1650	2200	2750	3300	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3″	.....	1800	2400	3000	3600	4200	.....	.....	.....	.....	.....	.....	.....	.....	.....
3¼″	.....	1950	2600	3250	3900	4550	.....	.....	.....	.....	.....	.....	.....	.....	.....
3½″	.....	2100	2800	3500	4200	4900	5600	.....	.....	.....	.....	.....	.....	.....	.....
3¾″	.....	.....	3000	3750	4500	5250	6000	.....	.....	.....	.....	.....	.....	.....	.....
4″	.....	.....	3200	4000	4800	5600	6400	7200	.....	.....	.....	.....	.....	.....	.....
4¼″	.....	.....	3400	4250	5100	5950	6800	7650	.....	.....	.....	.....	.....	.....	.....
4½″	.....	.....	3600	4500	5400	6300	7200	8100	9000	.....	.....	.....	.....	.....	.....
4¾″	.....	.....	3800	4750	5700	6650	7600	8550	9500	.....	.....	.....	.....	.....	.....
5″	.....	.....	.....	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000
5½″	.....	.....	.....	5500	6600	7700	8800	9900	11000	12100	13200	14300	15400	16500	17600
6″	.....	.....	.....	.....	7200	8400	9600	10800	12000	13200	14400	15600	16800	18000	19200
6½″	.....	.....	.....	.....	7800	9100	10400	11700	13000	14300	15600	16900	18200	19500	20800
7″	.....	.....	.....	.....	.....	9800	11200	12600	14000	15400	16800	18200	19600	21000	22400
7½″	.....	.....	.....	.....	.....	10500	12000	13500	15000	16500	18000	19500	21000	22500	24000
8″	.....	.....	.....	.....	.....	.....	12800	14400	16000	17600	19200	20800	22400	24000	25600
8½″	.....	.....	.....	.....	.....	.....	13600	15300	17000	18700	20400	22100	23800	25500	27200
9″	.....	.....	.....	.....	.....	.....	.....	16200	18000	19800	21600	23400	25200	27000	28800
9½″	.....	.....	.....	.....	.....	.....	.....	17100	19000	20900	22800	24700	26600	28500	30400
10″	.....	.....	.....	.....	.....	.....	.....	.....	20000	22000	24000	26000	28000	30000	32000
10½″	.....	.....	.....	.....	.....	.....	.....	.....	21000	23100	25200	27300	29400	31500	33600
11″	.....	.....	.....	.....	.....	.....	.....	.....	22000	24200	26400	28600	30800	33000	35200

BEARING PRESSURE FOR LOCOMOTIVE JOURNALS.

Based on Pressure of 300 Pounds per Square Inch of Projected Area. These Figures show Safe Allowance for Tender Journals.

Diameter of Journal.	LENGTH OF JOURNAL.														
	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″	12″	13″	14″	15″	16″
2″	1200	1800	2400	3000	3600	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2¼″	1350	2025	2700	3375	4050	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2½″	1500	2250	3000	3750	4500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2¾″	1650	2475	3300	4125	4950	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3″	.....	2700	3600	4500	5400	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3¼″	.....	2925	3900	4875	5850	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3½″	.....	3150	4200	5250	6300	7350	8400	.....	.....	.....	.....	.....	.....	.....	.....
3¾″	.....	.....	4500	5625	6750	7875	9000	.....	.....	.....	.....	.....	.....	.....	.....
4″	.....	.....	4800	6000	7200	8400	9600	.....	.....	.....	.....	.....	.....	.....	.....
4¼″	.....	.....	5100	6375	7650	8925	10200	11475	12750	.....	.....	.....	.....	.....	.....
4½″	.....	.....	5400	6750	8100	9450	10800	12150	13500	.....	.....	.....	.....	.....	.....
4¾″	.....	.....	5700	7125	8550	9975	11400	12825	14250	.....	.....	.....	.....	.....	.....
5″	.....	.....	.....	7500	9000	10500	12000	13500	15000	16500	18000	.....	.....	.....	.....
5½″	.....	.....	.....	8250	9900	11550	13200	14850	16500	18150	19800	.....	.....	.....	.....
6″	.....	.....	.....	.....	10800	12600	14400	16200	18000	19800	21600	.....	.....	.....	.....
6½″	.....	.....	.....	.....	11700	13650	15600	17550	19500	21450	23400	.....	.....	.....	.....
7″	.....	.....	.....	.....	.....	14700	16800	18900	21000	23100	25200	27300	29400	.....	.....
7½″	.....	.....	.....	.....	.....	15750	18000	20250	22500	24750	27000	29250	31500	.....	.....
8″	.....	.....	.....	.....	.....	.....	19200	21600	24000	26400	28800	31200	33600	.....	.....
8½″	.....	.....	.....	.....	.....	.....	20400	23950	25500	28050	30600	33150	35700	.....	.....
9″	.....	.....	.....	.....	.....	.....	21600	24300	27000	29700	32400	35100	37800	.....	.....
9½″	.....	.....	.....	.....	.....	.....	.....	25650	28500	31350	34200	37050	39900	.....	.....
10″	.....	.....	.....	.....	.....	.....	.....	.....	30000	33000	36000	39000	42000	45000	48000
10½″	.....	.....	.....	.....	.....	.....	.....	.....	31500	34650	37800	40950	44100	47250	50400
11″	.....	.....	.....	.....	.....	.....	.....	.....	.....	36300	39600	42900	46200	49500	52800

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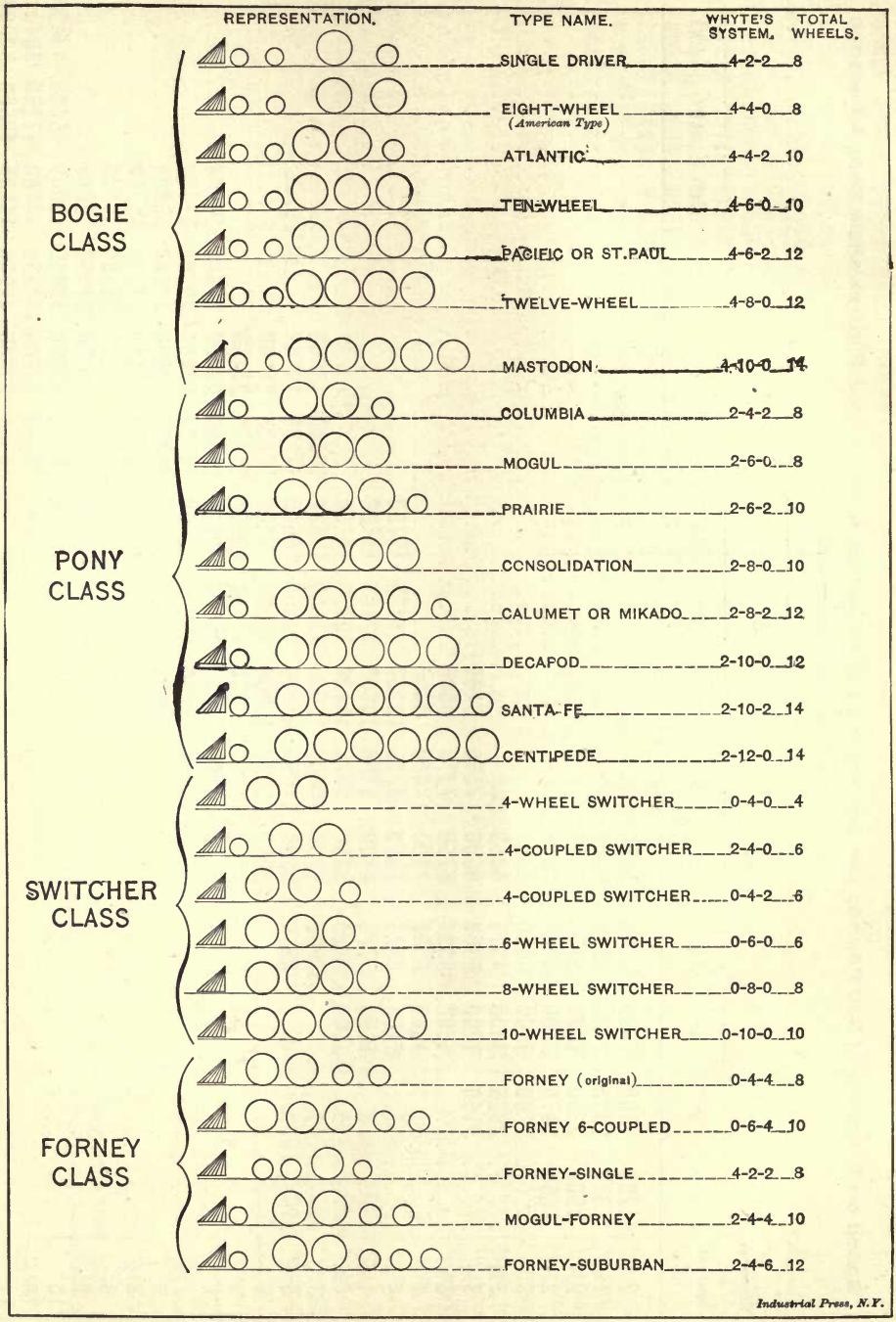
LOCOMOTIVE CLASSIFICATION



GAGES OF PRINCIPAL RAILROADS OF THE WORLD

Algiers—4 ft. 8½ in.—40 in.—3 ft. 6 in.
Argentine—5 ft. 6 in.—4 ft. 8½ in.—metre.
Austria—4 ft. 8½ in.—metre—2 ft. 6 in.
Australia—See South and West Australia.
Belgium—Metre—4 ft. 8½ in.
Borneo—Metre.
Brazil—Metre—5 ft. 3 in.
Bulgaria—4 ft. 8½ in.
Barbadoes—2 ft. 6 in.
Canada—4 ft. 8½ in.
Cape of Good Hope—3 ft. 6 in.
Ceylon—5 ft. 6 in.—2 ft. 6 in.
Chili—5 ft. 6 in.—4 ft. 8½ in.—4 ft. 2 in.
China—4 ft. 8½ in.
Columbia—3 ft.
Cuba—4 ft. 8½ in.
Denmark—4 ft. 8½ in.—metre.
Dutch Indies—3 ft. 6 in.
Ecuador—3 ft. 6 in.
Egypt—4 ft. 8½ in.—3 ft. 6 in.
England—4 ft. 8½ in.
Finland—5 ft.—2 ft. 5½ in.
France—4 ft. 8½ in.—metre—2 ft. 7½ in.
Germany—4 ft. 8½ in.—metre—29½ in.
Greece—4 ft. 8½ in.—metre.
Guatemala—3 ft.
Holland—4 ft. 8½ in.
Hungary—4 ft. 8½ in.—metre—2 ft. 6 in.
India—5 ft. 6 in.—metre—2 ft. 6 in.
Ireland—5 ft. 3 in.—3 ft.
Italy—4 ft. 8½ in.—metre—3 ft. 2 in.
Japan—3 ft. 6 in.
Jamaica—4 ft. 8½ in.
Mexico—4 ft. 8½ in.—3 ft.
Newfoundland—3 ft. 6 in.
New South Wales—4 ft. 8½ in.
New Zealand—3 ft. 6 in.
Nicaragua—3 ft. 6 in.
Norway—4 ft. 8½ in.—40 in.—29½ in.
Nova Scotia—4 ft. 8½ in.
Paraguay—5 ft. 6 in.
Panama—5 ft.
Peru—4 ft. 8½ in.—3 ft.
Porto Rico—4 ft. 8½ in.—3 ft.
Portugal—5 ft. 6 in.— metre.
Queensland—3 ft. 6 in.
Russia—5 ft.
Servia—4 ft. 8½ in.
Scotland—4 ft. 8½ in.
South Australia—5 ft. 3 in.
Spain—5 ft. 6 in.—metre.
Sweden—4 ft. 8½ in.—3 ft. 6 in.—2 ft. 7½ in.
Siberia—5 ft.
Switzerland—4 ft. 8½ in.—metre.
Siam—4 ft. 8½ in.
Tasmania—3 ft. 6 in.
Transvaal—3 ft. 6 in.
Turkey (in Europe)—4 ft. 8½ in.
Turkey (in Asia)—4 ft. 8½ in.—metre.
United States—4 ft. 8½ in.—4 ft. 9 in.—3 ft.
Uruguay—4 ft. 8½ in.
Venezuela—3 ft. 6 in.—2 ft.
Victoria—5 ft. 3 in.
Western Australia—3 ft. 6 in.

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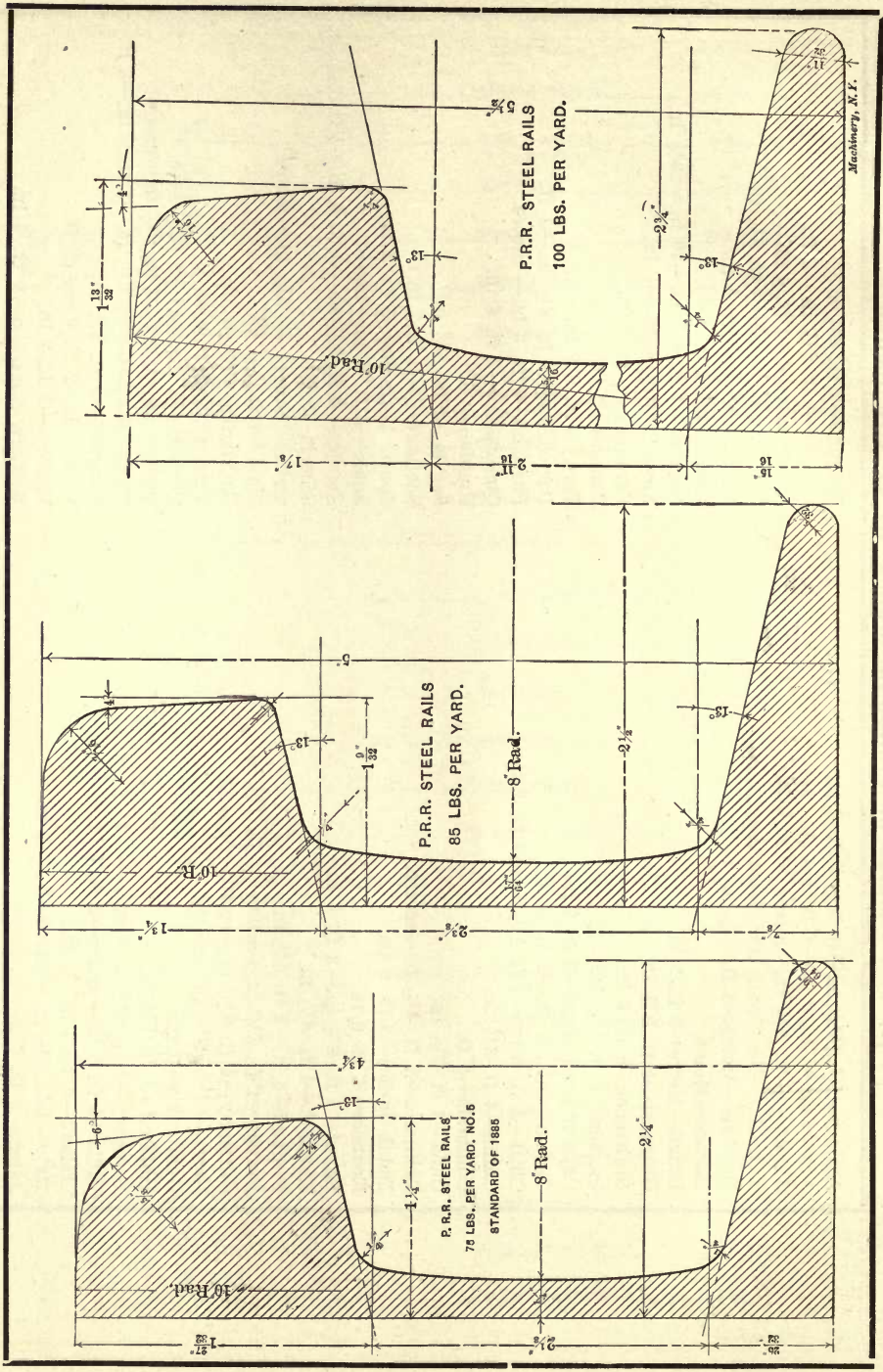
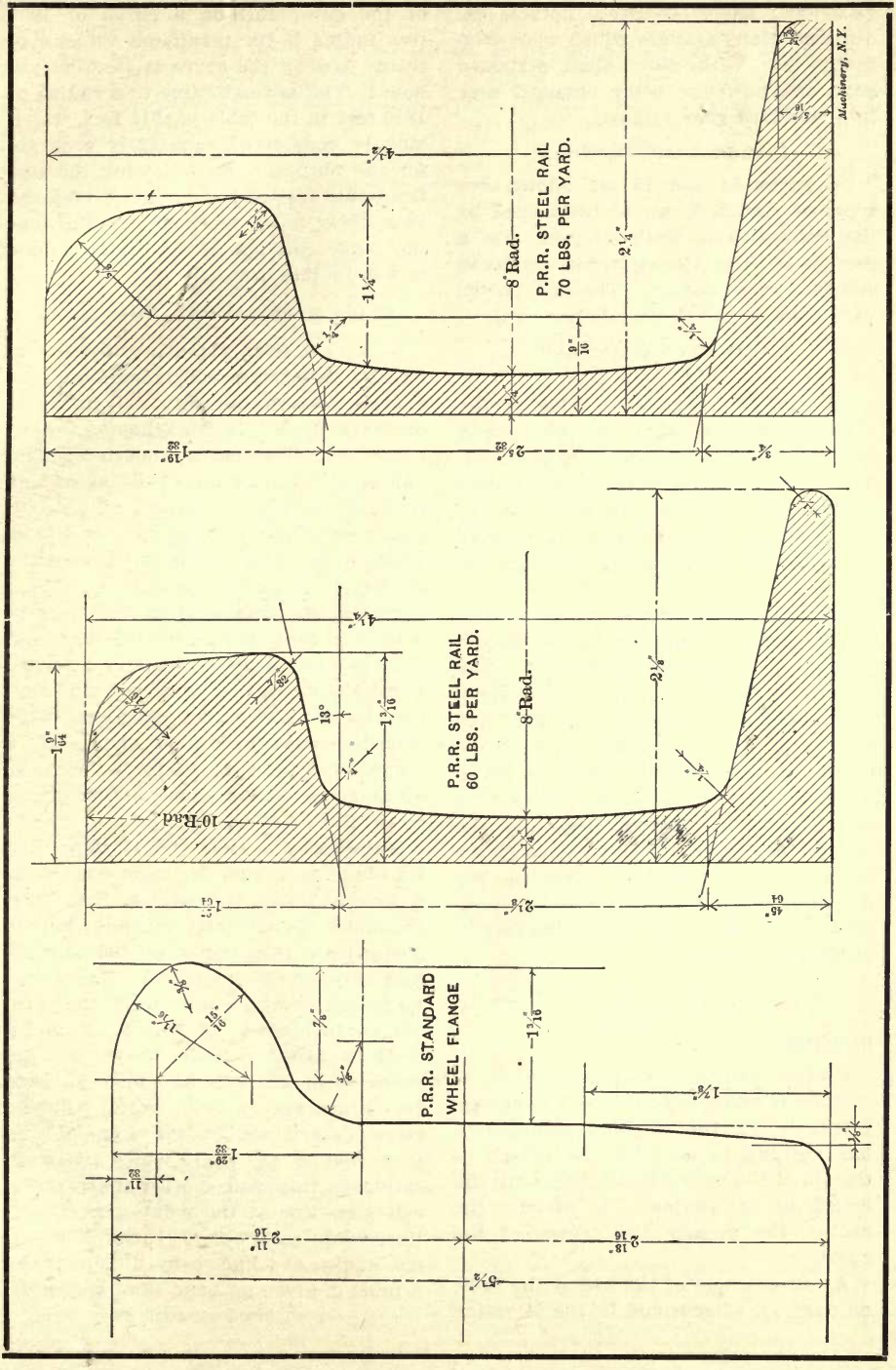
PENNSYLVANIA RAILROAD STANDARD RAIL SECTIONS—I



MACHINERY'S Data Sheet No. 21 (Railway Edition). Explanatory note: Page 16.

PENNSYLVANIA RAILROAD STANDARD RAIL SECTIONS AND WHEEL FLANGES—II



MACHINERY'S Data Sheet No. 21 (Railway Edition). Explanatory note: Page 16.

(3.28-foot) gage, constitute notable exceptions. Many systems which were originally laid with other than standard gage are, however, being changed over into standard gage systems.

Standard Rail Sections

On pages 14 and 15 are shown five types of standard rail sections used by the Pennsylvania Railroad, and also a section of the Pennsylvania Railroad standard wheel flange. The rails shown vary from 60 to 100 pounds per yard.

Elevation on Outer Rail of Curves

On page 17 is given a table of the elevation of the outer rail on curves, for different velocities in miles per hour. The degree of the curve and the radius of the curve in feet are given in the two left-hand columns, and the velocity in miles per hour at the top of the columns.

The expression "degree of curve" may require some explanation to persons not familiar with railroad track work. The degree of a curve is the center angle that would be subtended by a chord 100 feet long. For curves from 1 to 10 degrees the radius may be found by dividing 5730 feet, which is the radius of a one-degree curve, by the degree of the curve. The results are sufficiently accurate for all practical purposes, but for sharp curves, that is, for those exceeding 10 degrees, the following formula should be used:

$$R = \frac{50}{\sin D}$$

in which

R = the radius of the curve, and

D = the angle of the curve in degrees.

It is evident that the degree of a curve has nothing to do with the length of the arc of the curve, but merely with the length of the radius. The shorter the radius, the greater the degree of the curve.

As an example of the use of the table on page 17, what would be the elevation of the outer rail on a curve of 1900 feet radius if the maximum velocity of trains passing the curve is 45 miles per hour? The nearest value to a radius of 1900 feet in the table is 1910 feet, which may be considered sufficiently accurate for the purpose. By following the line from 1910 feet to the column giving the velocity in miles per hour, we find that the outer rail should be elevated four inches in this case.

Frogs, Switches and Cross-overs

As a rule, men who are primarily interested in machine construction are, for obvious reasons, not very well informed on track work. It often happens, however, that draftsmen, superintendents and others who have no training in this class of work are required to lay out, approve, or order industrial track systems to be used inside of a machine shop or in the yards outside. It is then necessary to decide upon the various details in connection with the frogs and switches, and some elementary information relating to this work will undoubtedly be of value to any man who is, or expects some day to be placed, in a responsible position where he may be occasionally called upon to carry out work of this character.

Switches are used for leading the wheels of cars from the main track onto a turn-out track. It is evident that when the outer switch rail reaches the opposite main rail, the wheel flange must pass through the main rail. The device by means of which the rail of the turn-out curve crosses the rail of the main track is called a frog, the general appearance of which is as shown on page 18. Frogs are made of various dimensions, determined by the angle of the frog, that is, the angle which the main rail gage line makes with the turn-out rail gage line at the point where these lines cross each other. Frogs of different angles are known by numbers, and a table is given on page 18 of frog num-

(Continued on page 24.)

ELEVATION OF OUTER RAIL ON CURVES IN INCHES.

Curve.		Velocity in Miles per Hour.													Deg.
Deg.	Feet.	10	15	20	25	30	35	40	45	50	55	60	65	70	
1	5730	0	1/8	1/4	3/8	5/8	3/4	1 1/8	1 3/8	1 5/8	2	2 3/8	2 3/4	3 1/4	1
2	2865	1/8	3/8	1/2	7/8	1 1/2	1 5/8	2 1/8	2 5/8	3 1/4	4	4 3/4	5 1/2	6 1/2	2
3	1910	1/4	1/2	3/4	1 1/4	1 3/4	2 3/8	3 1/8	4	4 7/8	6	7 1/8	8 3/8	9 3/4	3
4	1432	1/4	5/8	1 1/8	1 5/8	2 3/8	3 1/4	4 1/4	5 3/8	6 5/8	8	9 1/2	...	...	4
5	1146	3/8	3/4	1 1/4	2	3	4	5 1/4	6 5/8	8 1/4	...	...	...	...	5
6	955	3/8	1	1 5/8	2 1/2	3 1/2	4 7/8	6 1/4	8	...	...	...	...	...	6
7	818	1/2	1 1/8	1 7/8	2 7/8	4 1/8	5 5/8	7 3/8	...	...	...	...	...	...	7
8	716	1/2	1 1/4	2 1/8	3 1/4	4 3/4	6 1/2	8 3/8	...	...	...	...	...	...	8
9	636	5/8	1 3/8	2 3/8	3 3/4	5 3/8	7 1/4	...	...	...	...	...	...	...	9
10	573	3/4	1 1/2	2 5/8	4 1/8	5 7/8	8 1/8	...	...	...	...	...	...	...	10
11	521	3/4	1 3/4	2 7/8	4 5/8	6 1/2	8 7/8	...	...	...	...	...	...	...	11
12	477	7/8	1 7/8	3 1/8	4 7/8	7 1/8	...	...	...	...	...	...	...	...	12
13	441	7/8	2	3 3/8	5 3/8	7 3/4	...	...	...	...	...	...	...	...	13
14	409	1	2 1/8	3 3/8	5 3/4	8 3/8	...	...	...	...	...	...	...	...	14
15	382	1	2 1/4	3 7/8	6 1/4	8 7/8	...	...	...	...	...	...	...	...	15
16	358	1 1/8	2 1/2	4 1/4	6 5/8	...	...	...	...	...	...	...	...	...	16
17	337	1 1/4	2 5/8	4 1/2	7	...	...	...	...	...	...	...	...	...	17
18	318	1 1/4	2 3/4	4 3/4	7 1/2	...	...	...	...	...	...	...	...	...	18
19	301	1 3/8	2 7/8	5	7 3/4	...	...	...	...	...	...	...	...	...	19
20	286	1 3/8	3 1/8	5 1/4	8 1/8	...	...	...	...	...	...	...	...	...	20

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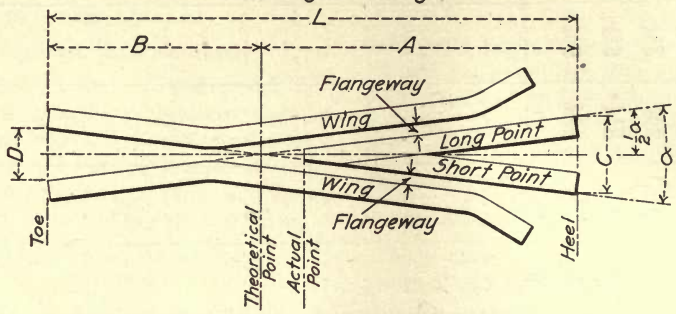
FROGS, SWITCHES AND CROSS-OVERS—I

Rigid Frogs.



Formulas for Rigid Frogs

N = no. of frog,
L = length over all,
C = heel spread,
D = toe spread,
α = angle of frog.

$$N = \frac{L}{C + D} \qquad \tan \tfrac{1}{2}\alpha = \frac{1}{2N}$$

$$C = 2A \times \tan \tfrac{1}{2}\alpha = \frac{A}{N}$$

$$D = 2B \times \tan \tfrac{1}{2}\alpha = \frac{B}{N}$$

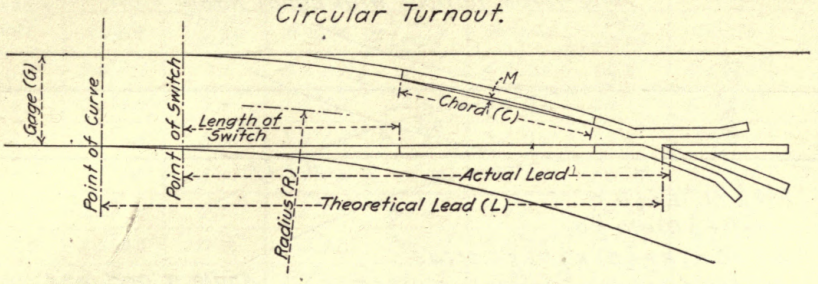
There are three types of rigid frogs.
1. Bolted: Filling in flangeway and held together by bolts.
2. Clamped: Filling in flangeway and held together by clamps.
3. Riveted: Rail bases riveted to a base plate.

Table of Frog Numbers and Angles.

Number	Angle	Number	Angle	Number	Angle	Number	Angle	Number	Angle	Number	Angle
1½	36°52′	3	18°55′	5	11°25′	8	7°09′	12	4°46′	18	3°11′
1¾	31°53′	3¼	17°30′	5½	10°23′	8½	6°44′	13	4°24′	19	3°01′
2	28°04′	3½	16°16′	6	9°32′	9	6°22′	14	4°05′	20	2°52′
2¼	25°03′	3¾	15°11′	6½	8°48′	9½	6°02′	15	3°49′		
2½	22°37′	4	14°15′	7	8°10′	10	5°43′	16	3°35′		
2¾	20°37′	4½	12°41′	7½	7°38′	11	5°12′	17	3°22′		

FROGS, SWITCHES AND CROSS-OVERS—II

Circular Turnout.



G = gage (inside width between rail-heads),
R = radius of curve,
L = theoretical lead of switch,
C = chord (see illustration above),
M = middle ordinate (see illustration),
N = number of frog (see Sheet I),
α = frog angle (see Sheet I),
δ = degree of curve.

$$L = 2G \times N = (R + \tfrac{1}{2}G) \sin \alpha$$

$$R = 2G \times N^2 = \frac{50}{\sin \frac{1}{2}\delta} = \frac{L^2}{2G}$$

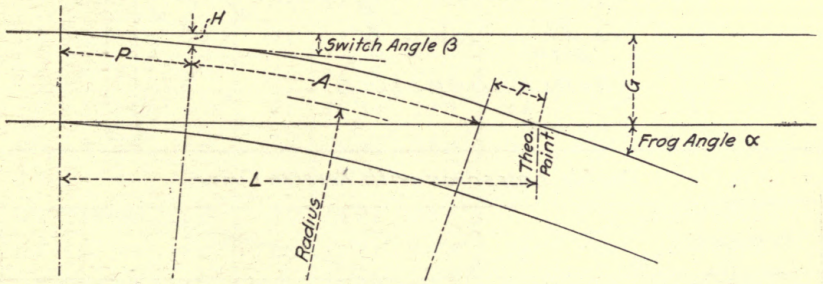
$$\cos \alpha = \frac{R - \frac{1}{2}G}{R + \frac{1}{2}G} \; ; \; \tan \frac{1}{2}\alpha = \frac{G}{L}$$

$$R = \tfrac{1}{2}\left(\frac{(\frac{1}{2}C)^2}{M} + M\right)$$

$$\sin \tfrac{1}{2}\delta = \frac{50}{R}$$

$$R = \frac{G}{\text{vers } \alpha} - \frac{1}{2}G$$

Turnout Using Straight Frog and Switch.



H = heel spread of switch,
T = distance from theoretical point to toe of frog,

$$T + \tfrac{1}{2}G = \frac{G - H - T \sin \alpha}{\cos \beta - \cos \alpha}$$

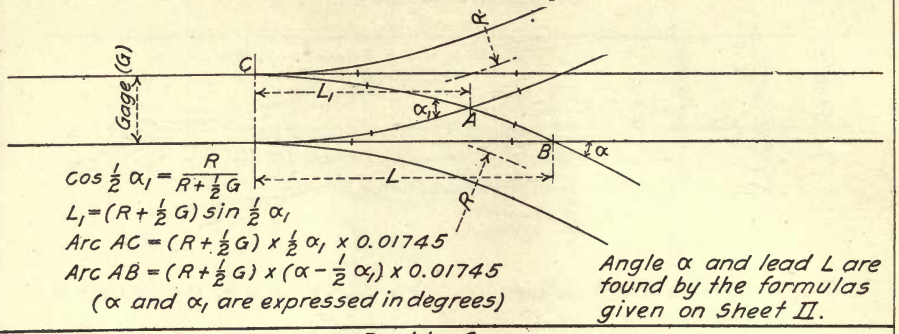
$$L = (R + \tfrac{1}{2}G)(\sin \alpha - \sin \beta) + (T \times \cos \alpha) + P$$

Length of arc $A = (\alpha - \beta)(R + \frac{1}{2}G) \times 0.01745$
(α and β are expressed in degrees)

P = length of switch,
β = switch angle.
Otherwise same notation as above.

FROGS, SWITCHES AND CROSS-OVERS—III

Three-Throw Turnout with Equal Radii.



$\cos \frac{1}{2}\alpha_1 = \frac{R}{R+\frac{1}{2}G}$

$L_1 = (R+\frac{1}{2}G)\sin\frac{1}{2}\alpha_1$

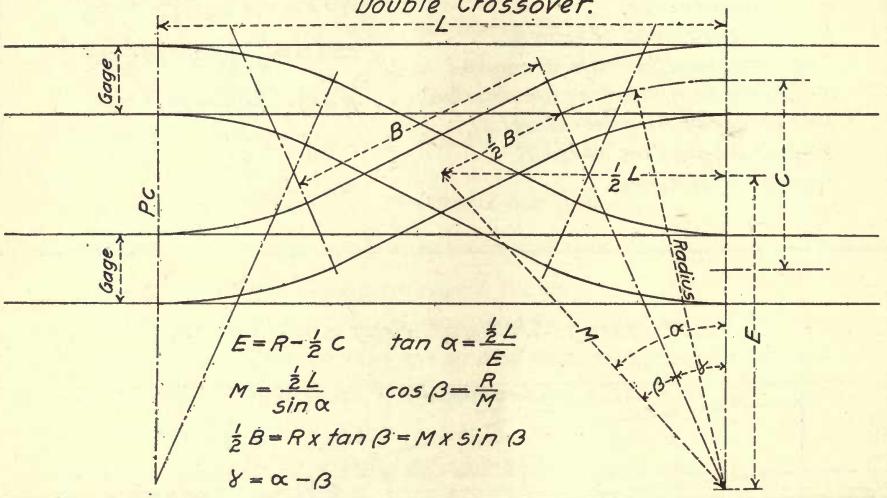
Arc $AC = (R+\frac{1}{2}G) \times \frac{1}{2}\alpha_1 \times 0.01745$

Arc $AB = (R+\frac{1}{2}G) \times (\alpha - \frac{1}{2}\alpha_1) \times 0.01745$

(α and α_1 are expressed in degrees)

Angle α and lead L are found by the formulas given on sheet II.

Double Crossover.



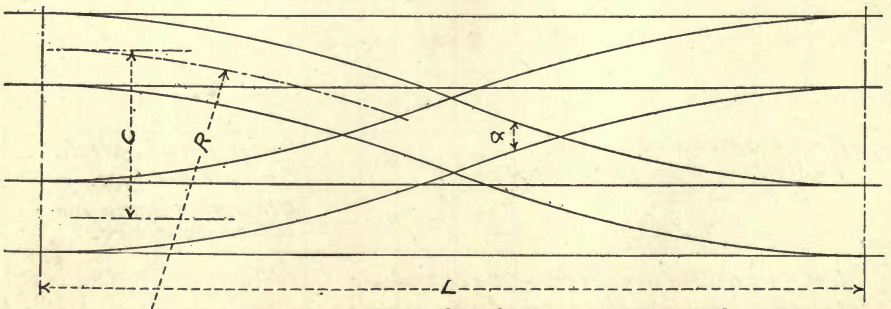
$E = R - \frac{1}{2}C$ $\quad \tan\alpha = \frac{\frac{1}{2}L}{E}$

$M = \frac{\frac{1}{2}L}{\sin\alpha}$ $\quad \cos\beta = \frac{R}{M}$

$\frac{1}{2}B = R \times \tan\beta = M \times \sin\beta$

$\gamma = \alpha - \beta$

Double Crossover with Reverse Curve.



$L = \sqrt{4RC - C^2}$ $\quad R = \frac{L^2 + C^2}{4C}$ $\quad \tan\frac{1}{2}\alpha = \frac{C}{L}$

FROGS, SWITCHES AND CROSS-OVERS—IV

Radius, Feet	Gage 2'6"		Gage 3'0"		Gage 3'4"		Gage 3'6"	
	Angle	Theo. Lead	Angle	Theo. Lead	Angle	Theo. Lead	Angle	Theo. Lead
10	38°57′	7′1″	42°21′	7′9″	44°25′	8′2″	45°24′	8′4″
12	35°46′	7′9″	38°57′	8′6″	40°53′	8′11″	41°48′	9′2″
14	33°16′	8′4″	36°15′	9′2″	38°05′	9′8″	38°57′	9′11″
16	31°14′	8′11″	34°03′	9′10″	35°58′	10′4″	36°36′	10′7″
18	29°32′	9′6″	32°12′	10′5″	33°51′	10′11″	34°38′	11′3″
20	28°04′	10′0″	30°38′	10′11″	32°12′	11′7″	32°57′	11′10″
25	25°13′	11′2″	27°32′	12′3″	29°00′	12′11″	29°38′	13′3″
30	23°04′	12′3″	25°13′	13′5″	26°32′	14′2″	27°09′	14′6″
35	21°24′	13′3″	23°24′	14′6″	24°37′	15′3″	25°13′	15′8″
40	20°03′	14′2″	21°55′	15′6″	23°04′	16′4″	23°38′	16′9″
50	17°58′	15′10″	19°39′	17′4″	20°42′	18′3″	21°12′	18′8″
60	16°26′	17′4″	17°58′	19′0″	18°56′	20′0″	19°23′	20′6″
70	15°13′	18′8″	16°39′	20′6″	17°33′	21′7″	17°58′	22′2″
80	14°15′	20′0″	15°36′	21′11″	16°26′	23′1″	16°50′	23′8″
90	13°27′	21′3″	14°42′	23′3″	15°30′	24′6″	15°53′	25′1″
100	12°46′	22′4″	13°58′	24′6″	14°43′	25′10″	15°04′	26′5″

Radius, Feet	Gage 3'8"		Gage 4'8½"			Gage 4'8½"				
	Angle	Theo. Lead	Radius, Feet	Angle	Theo. Lead	Number	Angle	Theo. Lead	Radius	Degree of Curve
10	46°21′	8′7″	30	31°18′	16′10″	4	14°15′	37′8″	150.6′	38°46′
12	42°42′	9′5″	40	27°16′	19′5″	4½	12°41′	42′4″	190.6′	30°24′
14	39°47′	10′2″	50	24°29′	21′8″	5	11°25′	47′1″	235.4′	24°32′
16	37°24′	10′10″	60	22°24′	23′9″	5½	10°23′	51′9″	284.8′	20°13′
18	35°24′	11′6″	70	20°47′	25′8″	6	9°32′	56′6″	338.9′	16°58′
20	33°41′	12′1″	80	19°28′	27′5″	6½	8°48′	61′2″	397.8′	14°26′
25	30°18′	13′6″	90	18°22′	29′1″	7	8°10′	65′11″	461.3′	12°27′
30	27°46′	14′10″	100	17°27′	30′8″	7½	7°38′	70′7″	529.6′	10°50′
35	25°47′	16′0″	110	16°39′	32′2″	8	7°09′	75′4″	602.6′	9°31′
40	24°10′	17′1″	120	15°57′	33′7″	8½	6°44′	80′0″	680.3′	8°26′
50	21°41′	19′2″	130	15°20′	35′0″	9	6°22′	84′9″	762.6′	7°31′
60	19°50′	21′0″	140	14°39′	36′4″	9½	6°02′	89′5″	849.7′	6°45′
70	18°23′	22′8″	150	14°17′	37′7″	10	5°43′	94′2″	941.6′	6°05′
80	17°13′	24′3″	160	13°50′	38′10″	11	5°12′	103′7″	1139.3′	5°02′
90	16°15′	25′8″	170	13°25′	40′0″	12	4°46′	113′0″	1355.9′	4°14′
100	15°26′	27′1″	180	13°03′	41′2″					

Contributed by Frank W. Holcomb, MACHINERY'S Data Sheet No. 131. Explanatory note: Page 16.

TABLE OF WEIGHT OF PLAIN TIRES.

Diam. of Wheel Center.	3 Inches Thick.		3½ Inches Thick.		4 Inches Thick.		Diam. of Wheel Center.	3 Inches Thick.		3½ Inches Thick,		4 Inches Thick.	
	6 Ins. Wide.	6½ Ins. Wide.	6 Ins. Wide.	6½ Ins. Wide.	6 Ins. Wide.	6½ Ins. Wide.		6 Ins. Wide.	6½ Ins. Wide.	6 Ins. Wide.	6½ Ins. Wide.	6 Ins. Wide.	6½ Ins. Wide,
21	413	446	487	526	563	609	53	963	1040	1122	1212	1283	1388
22	430	464	506	547	585	633	54	980	1059	1142	1234	1306	1412
23	447	483	526	569	608	657	55	997	1078	1162	1255	1328	1437
24	464	502	546	590	630	682	56	1014	1096	1182	1277	1351	1461
25	481	520	566	612	653	706	57	1031	1115	1202	1298	1373	1485
26	499	539	586	633	675	731	58	1049	1133	1221	1320	1396	1510
27	516	557	606	655	698	755	59	1066	1152	1241	1341	1418	1534
28	533	576	626	676	720	779	60	1083	1171	1261	1363	1441	1558
29	550	595	645	697	743	804	61	1100	1189	1281	1384	1463	1583
30	567	613	665	719	765	828	62	1117	1208	1301	1406	1486	1607
31	584	632	685	740	788	852	63	1135	1226	1321	1427	1508	1631
32	602	650	705	762	810	877	64	1152	1245	1341	1449	1531	1656
33	619	669	725	783	833	901	65	1169	1263	1360	1470	1553	1680
34	636	687	745	805	855	925	66	1186	1282	1380	1491	1576	1705
35	653	706	765	826	878	950	67	1203	1301	1400	1513	1598	1729
36	670	725	784	848	900	974	68	1220	1319	1420	1534	1621	1753
37	688	743	804	869	923	998	69	1238	1338	1440	1556	1643	1778
38	705	762	824	891	945	1023	70	1255	1356	1460	1577	1666	1802
39	722	780	844	912	968	1047	71	1272	1375	1480	1599	1688	1826
40	739	799	864	934	990	1071	72	1289	1394	1499	1620	1711	1851
41	756	818	884	955	1013	1096	73	1306	1412	1519	1642	1733	1875
42	774	836	904	976	1035	1120	74	1324	1431	1539	1663	1756	1899
43	791	855	923	998	1058	1144	75	1341	1449	1559	1685	1778	1925
44	808	873	943	1019	1080	1169	76	1358	1468	1579	1706	1801	1948
45	825	892	963	1041	1103	1193	77	1375	1486	1599	1728	1823	1972
46	842	910	983	1062	1126	1218	78	1392	1505	1619	1749	1846	1997
47	860	929	1003	1084	1148	1242	79	1410	1523	1638	1771	1868	2003
48	877	948	1023	1105	1171	1266	80	1427	1542	1658	1792	1891	2027
49	894	966	1043	1127	1193	1291	81	1444	1560	1678	1814	1913	2051
50	911	985	1063	1148	1216	1315	82	1461	1579	1698	1835	1936	2076
51	928	1003	1082	1170	1238	1339	83	1479	1597	1717	1857	1958	2100
52	945	1022	1102	1191	1261	1364	84	1496	1616	1737	1878	1981	2124

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TABLE OF WEIGHT OF FLANGED TIRES.

Diam. of Wheel Center.	3 inches Thick.		3½ inches Thick.		4 inches Thick.		Diam. of Wheel Center.	3 inches Thick.		3½ inches Thick.		4 inches Thick.	
	5½ ins Wide.	5¾ Ins. Wide	5½ Ins. Wide.	5¾ Ins. Wide	5½ Ins. Wide.	5¾ Ins. Wide		5½ Ins. Wide.	5¾ Ins. Wide.	5½ Ins. Wide.	5¾ Ins. Wide.	5½ Ins. Wide.	5¾ Ins. Wide.
21	401	417	469	489	540	562	53	936	974	1083	1127	1231	1282
22	418	435	489	508	562	585	54	953	991	1102	1147	1253	1304
23	435	452	508	528	583	607	55	970	1009	1121	1166	1274	1327
24	451	470	527	548	605	630	56	986	1026	1140	1186	1296	1349
25	468	487	546	568	626	652	57	1003	1043	1159	1206	1318	1372
26	485	504	565	588	648	675	58	1020	1060	1178	1226	1339	1394
27	502	522	584	608	670	697	59	1037	1078	1198	1246	1361	1417
28	518	539	604	628	691	720	60	1053	1096	1217	1266	1382	1439
29	535	556	623	648	713	742	61	1070	1113	1236	1286	1404	1462
30	551	574	642	668	734	765	62	1087	1130	1255	1306	1426	1484
31	568	591	661	688	756	787	63	1104	1148	1274	1326	1447	1507
32	585	609	680	708	778	810	64	1120	1165	1293	1346	1469	1529
33	602	626	699	728	799	832	65	1137	1183	1312	1366	1490	1552
34	619	643	718	748	821	855	66	1154	1200	1332	1386	1512	1574
35	635	661	738	768	842	877	67	1170	1217	1351	1406	1534	1597
36	652	678	757	788	864	900	68	1187	1235	1370	1426	1555	1619
37	669	696	776	808	886	922	69	1204	1252	1389	1446	1577	1642
38	686	713	795	828	907	945	70	1221	1269	1408	1466	1598	1664
39	702	730	814	847	929	967	71	1237	1287	1427	1486	1620	1687
40	719	748	833	867	950	990	72	1254	1304	1447	1505	1642	1709
41	736	765	853	887	972	1012	73	1271	1322	1466	1525	1663	1732
42	752	783	872	907	994	1035	74	1287	1339	1485	1545	1685	1754
43	769	800	891	927	1015	1057	75	1304	1356	1504	1565	1706	1777
44	786	817	910	947	1037	1080	76	1321	1374	1523	1585	1728	1799
45	803	835	929	967	1058	1102	77	1338	1391	1542	1605	1750	1822
46	819	852	948	987	1080	1125	78	1354	1409	1562	1625	1771	1844
47	836	870	968	1007	1102	1147	79	1371	1426	1581	1644	1793	1867
48	853	887	987	1027	1123	1169	80	1387	1444	1601	1664	1814	1889
49	869	904	1006	1047	1145	1192	81	1404	1462	1620	1684	1836	1901
50	886	922	1025	1067	1166	1214	82	1420	1479	1639	1704	1857	1924
51	903	939	1044	1087	1188	1237	83	1437	1497	1659	1723	1879	1946
52	920	956	1063	1107	1210	1259	84	1454	1514	1678	1743	1900	1968

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bers with their corresponding angles, the numbers being given from 1½ up to 20. Formulas are also given by means of which the frog number can be found when the angle is known, and the angle found when the frog number is known. As shown on page 18, dimension *L* is the length along the center line. This is, theoretically, the correct dimension to be measured for determining the frog angle. In practice, however, the length is usually measured along the gage line, because of convenience in taking the measurement in this way. As the angles are small, approximately correct results are obtained by inserting the dimension thus obtained in place of *L* in the formulas.

A circular turn-out is shown on page 19. In the illustration the various dimensions, such as theoretical lead, actual lead, radius, etc., are defined, and formulas for finding each are given. When a turn-out of this kind is being laid out, the angle can be determined when the radius and the gage are known, and when the angle has been found the corresponding frog to be used, as defined by its number, is determined from the table already referred to. The lower part on page 19 gives formulas for a turn-out using straight frog and switch. In this case the formulas are somewhat more complicated than in the simple circular turn-out.

On page 20 is shown a diagram of a three-throw turn-out, and formulas are given for determining the angle between the outer rails of the two turn-out curves. In the lower part of the same table is a diagram of a double crossover with straight crossing and curved switches, and also for a double crossover with reverse curve, formulas for the required angles and dimensions being given for both. On page 21 some of the dimensions which can be found by the formulas given in the previous tables have been tabulated and collected for six different gages. These tables give the radius in feet, the angle in degrees and minutes and the theoretical lead in feet and inches. A special table for 4-foot 8½-inch, or standard gage, is also included, which gives the number of frog, the corresponding angle, the theoretical lead, the radius of the turn-out curve and the degree of the curve.

Tables of Weights of Tires

On pages 22 and 23 are given two tables of the weights of tires of various dimensions, the table on page 22 being for plain tires, and that on page 23 for flanged tires. For example, if the diameter of the wheel center is 59 inches, then a plain tire 3 1/2 inches thick, and 6 1/2 inches wide will weigh approximately 1341 pounds, as found from the table on page 22. A flanged tire of the same dimensions, except only 5 3/4 inches wide, would weigh 1246 pounds, as found from the table on page 23.

Allowances for Shrinkage of Tires

The term "shrinking fit" is applied when a part which is to be held in position by being tightly fitted in a hole, is first turned a few thousandths of an inch larger than the hole, and then the diameter of the hole increased by heating, after which the central part is inserted into the heated part. When the outside part cools down, the consequent contraction of the metal causes it to grip the central part with a tremendous pressure. Locomotive tires are attached to their wheel centers by means of a shrinking fit. On page 25 are given the allowances for shrinkage for different diameters of tires. For example, if the wheel center is 40 inches in diameter, then the inside diameter of the tire should be made 39.958 inches, an allowance of 0.042 inch being made for shrinkage.

Tables of Speeds of Trains

On pages 26 and 27 are given two tables which will be found useful when making calculations relating to the speed

(Continued on page 38.)

PROPER ALLOWANCE FOR SHRINKAGE OF TIRES.

Diameter of Wheel Center.	Inside Diameter of Tire,	Allowance for Shrinkage.	Diameter of Wheel Center.	Inside Diameter of Tire.	Allowance for Shrinkage.
20	19.979	.021	53	52.945	.055
21	20.978	.022	54	53.944	.056
22	21.977	.023	55	54.943	.057
23	22.976	.024	56	55.942	.058
24	23.975	.025	57	56.941	.059
25	24.974	.026	58	57.940	.060
26	25.973	.027	59	58.939	.061
27	26.972	.028	60	59.937	.063
28	27.971	.029	61	60.936	.064
29	28.970	.030	62	61.935	.065
30	29.969	.031	63	62.934	.066
31	30.968	.032	64	63.933	.067
32	31.967	.033	65	64.932	.068
33	32.966	.034	66	65.931	.069
34	33.965	.035	67	66.930	.070
35	34.964	.036	68	67.929	.071
36	35.962	.038	69	68.928	.072
37	36.961	.039	70	69.927	.073
38	37.960	.040	71	70.926	.074
39	38.959	.041	72	71.925	.075
40	39.958	.042	73	72.924	.076
41	40.957	.043	74	73.923	.077
42	41.956	.044	75	74.922	.078
43	42.955	.045	76	75.921	.079
44	43.954	.046	77	76.920	.080
45	44.953	.047	78	77.919	.081
46	45.952	.048	79	78.918	.082
47	46.951	.049	80	79.917	.083
48	47.950	.050	81	80.916	.084
49	48.949	.051	82	81.915	.085
50	49.948	.052	83	82.914	.086
51	50.947	.053	84	83.912	.088
52	51.946	.054	..	.....	....

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EQUIVALENTS OF TIME AND SPACE TRAVERSED.

Miles per Hour.	Feet per Hour.	Feet per Minute.	Feet per Second.	Time per Mile.	Time per Mile.	Miles per Hour.	Feet per Hour.	Feet per Minute.	Feet per Second.	Time per Mile.	Time per Mile.
				Min. Sec.	Seconds.					Min. Sec.	Seconds.
1	5,280	88	1.46	60 ..	3,600	31	163,680	2,728	45.46	1 56	116
2	10,560	176	2.92	30 ..	1,800	32	168,960	2,816	46.92	1 52	112
3	15,840	264	4.38	20 ..	1,200	33	174,240	2,904	48.38	1 49	109
4	21,120	352	5.86	15 ..	900	34	179,520	2,992	49.86	1 45	105
5	26,460	440	7.32	12 ..	720	35	184,800	3,080	51.33	1 42	102
6	31,680	528	8.80	10 ..	600	36	190,080	3.168	52.80	1 40	100
7	36,960	616	10.26	8 34	514	37	195,360	3,256	54.26	1 37	97
8	42,240	704	11.73	7 30	450	38	200,640	3,344	55.73	1 34	94
9	47,520	792	13.19	6 40	400	39	205,920	3,432	57.19	1 32	92
10	52,800	880	14.66	6 ..	360	40	211,200	3,520	58.66	1 30	90
11	58,080	968	16.12	5 27	327	41	216,480	3,608	60.12	1 27	87
12	63,360	1,056	17.60	5 ..	300	42	221,760	3,696	61.60	1 25	85
13	68,640	1,144	19.06	4 36	276	43	227,040	3,784	63.06	1 23	83
14	73,920	1,232	20.52	4 17	257	44	232,320	3,872	64.52	1 21	81
15	79,200	1,320	22.00	4 ..	240	45	237,600	3,960	66.00	1 20	80
16	84,480	1,408	23.46	3 45	225	46	242,880	4,048	67.46	1 18	78
17	89,760	1,496	24.92	3 31	211	47	248,160	4,136	68.92	1 16	76
18	95,040	1,584	26.38	3 20	200	48	253,440	4,224	70.38	1 15	75
19	100,320	1,672	27.86	3 9	189	49	258,720	4,312	71.86	1 13	73
20	105,600	1,760	29.33	3 ..	180	50	264,000	4,400	73.33	1 12	72
21	110,880	1,848	30.80	2 51	171	51	269,280	4 488	74.80	1 10	70
22	116,160	1,936	32.26	2 43	163	52	274,560	4,576	76.26	1 9	69
23	121,440	2,024	33.73	2 36	156	53	279 840	4,664	77.73	1 7	67
24	126,720	2,112	35.19	2 30	150	54	285,120	4,752	79.19	1 6	66
25	132,000	2,200	36.66	2 24	144	55	290 400	4,840	80.66	1 5	65
26	137,280	2,288	38.12	2 18	138	56	295,680	4,928	82.12	1 4	64
27	142,560	2,376	39.60	2 13	133	57	300,960	5 016	83.60	1 3	63
28	147,840	2,464	41.06	2 8	128	58	306,240	5,10[illegible]	85.06	1 2	62
29	153,120	2,552	42.52	2 4	124	59	311,520	5,[illegible]92	86.52	1 1	61
30	158,400	2,640	44.00	2 ..	120	60	316,800	5,280	88.00	1 ..	60

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ROTATIVE SPEED TABLE FOR MILES PER HOUR.

Diameter in inches.	Circumference in feet.	Revolutions per mile.	Revolutions per Minute at Miles per Hour.							
			10	15	25	35	40	55	65	75
18	4.712	1119.76	186.62	279.94	466.55	653.17	746.48	1026.42	1213.03	1399.65
20	5.236	1008.4	168.07	252.1	420.17	588.24	672.28	924.38	1092.45	1260.52
22	5.759	916.8	152.4	229.2	381.6	534.	609.6	838.8	991.2	1143.6
24	6.283	838.4	139.7	209.6	349.3	489.	558.8	767.4	908.1	1047.8
26	6.81	775.3	129.2	193.8	323.	452.2	516.8	710.6	839.8	969.
28	7.36	720.3	120.	180.1	300.1	420.1	480.	660.1	780.1	900.1
30	7.85	672.6	112.1	168.15	280.25	392.35	448.4	616.55	728.65	840.75
32	8.377	630.3	105.05	157.57	262.62	367.67	420.2	577.77	682.82	787.87
33	8.64	611.1	101.85	152.8	254.65	356.5	407.40	560.2	662.05	763.9
34	8.901	593.2	98.8	148.3	247.1	345.9	395.2	543.5	642.3	741.1
36	9.42	560.5	93.4	140.1	233.5	326.9	373.6	513.7	607.1	700.5
37	9.686	545.1	90.8	136.3	227.1	317.9	363.2	499.5	590.3	681.1
38	9.95	530.6	88.4	132.4	220.8	309.2	353.6	486.	574.4	662.8
40	10.47	504.2	84.03	126.05	210 08	294.11	336.12	462.17	546.2	630.23
42	11.00	480.0	80.	120.	200.	280.	320.	440.	520.	600.
44	11.52	458.3	76.4	114.5	191.	267.4	305.6	420.1	496.6	573.
46	12.04	438.5	73.1	109.6	182.7	255.8	292.4	402.	475.1	548.2
48	12.57	420.0	70.	105.	180.	250.	280.	385.	460.	530.
50	13.00	403.4	67.2	100.85	168.	235.2	268.8	369.65	436.8	504.
52	13.61	387.9	64.6	97.	161.6	226.2	258.4	355.4	420.	484.6
54	14.14	373.4	62.2	93.3	155.5	217.7	248.8	342 1	404.3	466.5
56	14.66	360.2	60.03	90.05	150.1	210.13	240.12	330.17	390.22	450.25
58	15.18	347.8	57.9	86.9	144.8	202.7	231.6	318 5	376.4	434.3
60	15.71	336.1	56.01	84.02	141.	197.01	224.04	308.1	365.04	421.05
62	16.23	325.3	54.2	81.3	135.5	189.7	216.8	298.1	352.3	406.5
64	16.75	315.2	52.5	78.7	131.2	183.7	210.	288.7	341.2	393.7
66	17.28	305.5	50.9	76.4	127.3	178.2	203.6	280.	330.9	381.8
68	17.80	296.6	49.4	74.1	123.5	173.	197.6	271.7	321.1	370.6
70	18.36	288.1	48.0	72.	120.	168.	192.	264.	312.	360.
72	18.85	280.1	46.7	70.	116.7	163.4	186.8	256.8	303.5	350.2
78	20.42	258.6	43.1	64.6	107.7	150.8	172.4	237.	280.1	323.2
84	21.99	240.1	40.	60.	100.	140.	160.	220.	260.	300.
90	23.56	224.1	37.3	56.	92.3	129.6	149.2	205.2	241.5	278.8
96	25.16	210.1	35.	52.5	87.5	122.5	140.	192.5	227.5	262.5

The rate of miles per hour has been so chosen that by doubling any of them the intermediate speeds of 20, 30, 50, 70, 80, etc., can be had. The column of revolutions per mile gives revolutions per minute for 60 miles per hour. Almost any other speed can be found by adding two columns such as 10 and 75.

GRADES AND EFFECT ON HAULING CAPACITY.

GRADES.				LOADS.	
Per Cent.	Feet per Mile.	Length to Rise of 1 Foot.	Resistance in pounds per ton at 10 Miles per Hour.	Tons Hauled per 1000 pounds on Drivers.	
1	2	3	4	5	6
.1	5.28	1000.	6.5	38.4	30.8
.5	26.4	200.	14.1	17.7	14.1
1.	52.8	100.	23.6	10.6	8.4
1.5	79.2	66.66	34.7	7.2	5.7
2.	105.6	50.	44.5	5.5	4.4
2.5	132.	40.	54.	4.6	3.6
3.	158.4	33.33	69.9	3.8	3.
3.5	184.8	28.57	74.5	3.3	2.4
4.	211.2	25.	84.3	2.9	2.3
4.5	237.6	22.22	94.7	2.7	2.1
5.	264.	20.	104.6	2.3	1.8
5.5	290.4	18.18	114.7	2.1	1.7
6.	316.8	16.66	124.9	2.	1.6

Columns 1, 2, 3 and 4 explain themselves. Column 5 is based on the assumption that tractive power is one-quarter the weight on drivers. Column 6 is similar except that one-fifth the weight on drivers is assumed and it is therefore a more conservative calculation.

Resistance equals .3788 pounds per ton for a straight grade of 1 foot per mile.

CURVES

Degree.	Radius.	Equivalent to Grade of (Feet per mile.)
1	5730	1.32
2	2865	2.64
3	1910	3.96
4	1433	5.28
5	1146	6.60
6	955	7.92
7	819	9.24
8	717	10.6
9	637	11.9
10	574	13.2
12	478	15.8
14	410	18.5
16	359	21.1
18	320	23.8
20	288	26.4
22	262	29.
24	240	31.7
26	222	34.3
28	207	37.
30	193	39.6

The resistance of curves is taken as ½ pound per degree of curve, or equivalent to a grade of 1.32 feet per mile per degree. Dividing 5730 by degrees of curves gives radius in feet—not exact for short curves.

Curves on grades are sometimes eased by widening gage of track $\frac{1}{16}$ inch for each 2½ degrees of curve. Others reduce grade on curves from $\frac{2}{100}$ to $\frac{3}{100}$ of a foot per degree of curve. This equalizes the work of the locomotive.

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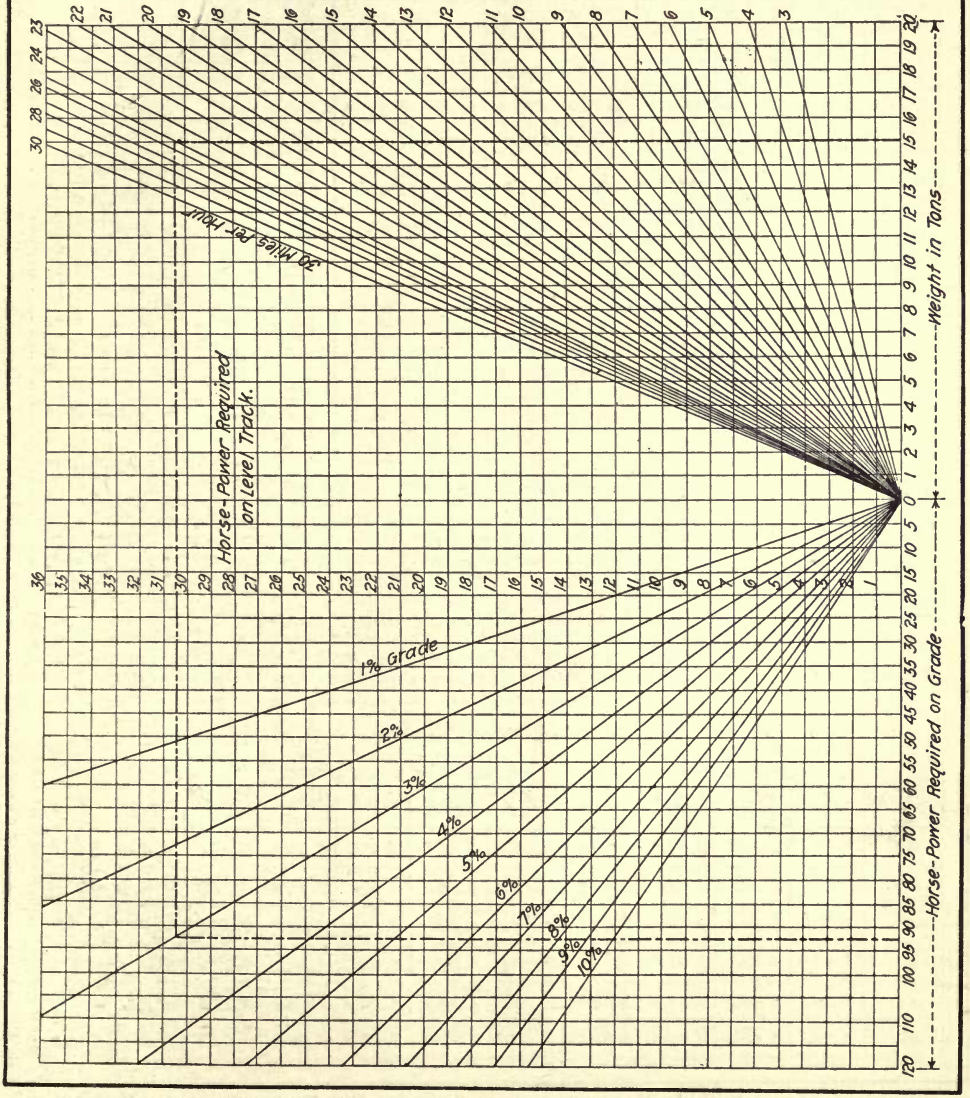
HORSEPOWER REQUIRED FOR MOVING CARS

Example:- Find Horse-Power required to move a car weighing 15 tons at a speed of 25 miles per hour, both on level track and up a 3 per cent grade.

Find weight in tons, 15, on right-hand vertical scale; follow horizontal line from this point to intersection with line for 25 miles per hour speed. From this intersection follow vertical line to scale for Horse-Power required on level track, reading off 30½ H.P. Follow the same vertical line further to intersection with 3 per cent grade line. From the intersection follow the horizontal line to the right-hand vertical scale, finding 93 H.P.



CONSTANTS FOR CALCULATING TRACTIVE FORCE—I

Values of $0.85d^2s$, for Calculating Tractive Power

Size of Cylinder	Value	Size of Cylinder	Value	Size of Cylinder	Value
9" x 14"	963.9	15" x 22"	4207.5	20" x 32"	10880.0
9" x 16"	1101.6	15" x 24"	4590.0	20" x 35"	11560.0
10" x 14"	1190.0	16" x 20"	4352.0	21" x 24"	8996.4
10" x 16"	1360.0	16" x 22"	4787.2	21" x 26"	9746.1
10" x 18"	1530.0	16" x 24"	5222.4	21" x 28"	10495.8
11" x 14"	1439.9	17" x 20"	4913.0	21" x 30"	11245.5
11" x 16"	1645.6	17" x 22"	5404.3	21" x 32"	11995.2
11" x 18"	1851.3	17" x 24"	5895.6	22" x 26"	10696.4
12" x 16"	1958.4	17" x 26"	6380.9	22" x 28"	11519.2
12" x 18"	2203.2	18" x 20"	5508.0	22" x 30"	12342.0
12" x 20"	2448.0	18" x 22"	6058.8	22" x 32"	13164.8
12" x 22"	2692.8	18" x 24"	6609.6	22" x 34"	13987.6
12" x 24"	2937.6	18" x 26"	7160.4	23" x 28"	12590.2
13" x 20"	2873.0	19" x 22"	6737.5	23" x 30"	13489.5
13" x 22"	3160.3	19" x 24"	7350.0	23" x 32"	14388.8
13" x 24"	3447.6	19" x 26"	7962.5	23" x 34"	15288.1
14" x 20"	3332.0	20" x 24"	8160.0	24" x 30"	14688.0
14" x 22"	3665.2	20" x 26"	8840.0	24" x 32"	15667.2
14" x 24"	3998.4	20" x 28"	9520.0	24" x 34"	16646.4
15" x 20"	3825.0	20" x 30"	10200.0		

Note:—The tables were compiled to simplify the use of the well-known formula $T = \frac{0.85Pd^2s}{D}$. To determine the tractive power of a locomotive, find from the above table the value of $0.85d^2s$, in which d is the diameter of the cylinder, s the stroke, and 0.85 the ratio of the M.E.P. (mean effective pressure) to the boiler pressure. Then, in the table of wheel diameters and boiler pressures find a value opposite the wheel diameter (being the given pressure divided by diameter of wheel), and multiply together the two values thus found. The result will be the total tractive power.

Example:— Find the tractive power of a 21 x 26-inch cylinder simple locomotive having driving wheels, 60 inches diameter and boiler pressure, 195 pounds. $0.85d^2s = 9746.1$ and the boiler pressure divided by the wheel diameter equals 3.250. Multiplying 9746.1 x 3.250 = 31,674.8 pounds, tractive power.

Table of Constants: Driving Wheel Diameters ÷ Boiler Pressures.

Driving wheel diameter, inches	Boiler pressure, pounds per square inch, gage.										
	175	180	185	190	195	200	205	210	215	220	225
48	3.646	3.750	3.854	3.959	4.053	4.157	4.261	4.365	4.469	4.573	4.678
49	3.571	3.673	3.776	3.878	3.980	4.082	4.184	4.286	4.388	4.490	4.592
50	3.500	3.600	3.700	3.800	3.900	4.000	4.100	4.200	4.300	4.400	4.500
51	3.431	3.529	3.627	3.725	3.824	3.922	4.020	4.118	4.216	4.314	4.412
52	3.365	3.462	3.558	3.654	3.750	3.846	3.942	4.038	4.135	4.231	4.327
53	3.302	3.396	3.491	3.585	3.679	3.774	3.868	3.962	4.057	4.151	4.245

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CONSTANTS FOR CALCULATING TRACTIVE FORCE—II

Table of Constants: Driving Wheel Diameters ÷ Boiler Pressures. (Continued)

Driving wheel diameter, inches	Boiler pressure, pounds per square inch, gage.										
	175	180	185	190	195	200	205	210	215	220	225
54	3.241	3.333	3.426	3.519	3.611	3.705	3.796	3.889	3.981	4.074	4.167
55	3.183	3.273	3.364	3.455	3.545	3.636	3.727	3.818	3.909	4.000	4.091
56	3.125	3.203	3.290	3.378	3.465	3.543	3.630	3.708	3.839	3.928	4.018
57	3.070	3.158	3.246	3.333	3.421	3.509	3.596	3.684	3.772	3.860	3.947
58	3.017	3.103	3.190	3.276	3.362	3.448	3.534	3.621	3.707	3.793	3.879
59	2.966	3.051	3.136	3.220	3.305	3.390	3.475	3.559	3.644	3.729	3.814
60	2.917	3.000	3.083	3.167	3.250	3.333	3.417	3.500	3.583	3.667	3.750
61	2.869	2.951	3.033	3.115	3.197	3.279	3.361	3.443	3.525	3.607	3.689
62	2.823	2.903	2.984	3.065	3.145	3.226	3.306	3.387	3.468	3.548	3.629
63	2.778	2.857	2.937	3.016	3.095	3.175	3.254	3.333	3.413	3.492	3.571
64	2.734	2.813	2.891	2.969	3.047	3.125	3.203	3.281	3.359	3.438	3.516
65	2.692	2.769	2.846	2.923	3.000	3.077	3.154	3.231	3.308	3.385	3.462
66	2.652	2.727	2.803	2.879	2.955	3.030	3.106	3.182	3.258	3.333	3.409
67	2.612	2.687	2.761	2.836	2.910	2.985	3.060	3.134	3.209	3.284	3.358
68	2.574	2.647	2.721	2.794	2.868	2.941	3.015	3.088	3.162	3.235	3.309
69	2.536	2.609	2.681	2.754	2.826	2.899	2.971	3.043	3.116	3.188	3.261
70	2.500	2.571	2.643	2.714	2.786	2.857	2.929	3.000	3.071	3.143	3.214
71	2.465	2.535	2.606	2.676	2.746	2.817	2.887	2.958	3.028	3.099	3.169
72	2.431	2.500	2.569	2.639	2.708	2.778	2.847	2.917	2.986	3.056	3.125
73	2.397	2.466	2.534	2.603	2.671	2.740	2.807	2.876	2.944	3.013	3.081
74	2.365	2.432	2.500	2.568	2.635	2.708	2.770	2.838	2.905	2.973	3.041
75	2.333	2.400	2.467	2.533	2.600	2.667	2.733	2.800	2.867	2.933	3.000
76	2.303	2.368	2.434	2.500	2.566	2.632	2.697	2.763	2.829	2.895	2.961
77	2.273	2.338	2.403	2.468	2.532	2.597	2.662	2.727	2.792	2.857	2.922
78	2.244	2.308	2.372	2.436	2.500	2.564	2.628	2.692	2.756	2.821	2.884
79	2.215	2.278	2.342	2.405	2.468	2.531	2.595	2.658	2.722	2.785	2.848
80	2.188	2.250	2.313	2.375	2.438	2.500	2.563	2.625	2.688	2.750	2.813
81	2.160	2.222	2.284	2.346	2.406	2.468	2.530	2.592	2.653	2.715	2.777
82	2.134	2.195	2.256	2.317	2.378	2.439	2.500	2.561	2.622	2.683	2.744
83	2.108	2.169	2.229	2.289	2.349	2.410	2.470	2.530	2.590	2.651	2.711
84	2.083	2.143	2.202	2.262	2.321	2.381	2.440	2.500	2.560	2.619	2.679

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INERTIA OF TRAINS.—I.

S Speed Miles per Hour, to be Attained in given Distance.	Tractive Force, Pounds per Ton (2000 Pounds), to Attain Speed S, in Distance D from Starting Point, $= 66.86 \frac{S^2}{D}$									
	100 Feet.	250 Feet.	500 Feet.	750 Feet.	1,000 Feet.	1,500 Feet.	2,000 Feet.	3,000 Feet.	4,000 Feet.	5,000 Feet.
4	10.69	4.28	2.14	1.42	1.07	.713	.535	.356	.267	.214
5	16.7	6.68	3.34	2.22	1.67	1.11	.835	.556	.417	.334
6	24.	9.6	4.8	3.2	2.4	1.6	1.2	.803	.603	.481
8	42.7	17.1	8.54	5.7	4.27	2.84	2.13	1.42	1.07	.854
10	66.8	26.7	13.35	8.91	6.68	4.45	3.34	2.22	1.67	1.33
12	96.	38.4	19.2	12.8	9.6	6.4	4.8	3.21	2.41	1.92
15	150.	60.	30.	20.	15.	10.	7.5	5.01	3.75	3.
20	267.	106.	53.4	35.6	26.7	17.8	13.35	8.9	6.67	5.34
25	.....	166.	83.4	55.6	41.7	22.8	20.85	11.4	10.42	8.34
30	.....	240.	120.	80.2	60.1	40.1	30.	20.	15.04	12.03
35	.....	326.	163.	108.	81.8	54.3	40.9	27.1	20.4	16.36
40	.....	.....	214.	142.	107.	71.3	53.5	35.6	26.7	21.4
45	.....	.....	270.	180.	135.	90.	67.6	45.	33.8	27.
50	.....	.....	334.	222.	167.	111.	83.5	55.6	41.7	33.4
55	.....	.....	404.	269.	202.	134.	101.	67.	55.5	40.4
60	.....	.....	.....	320.	240.	160.	120.	80.3	60.3	48.1
65	.....	.....	.....	376.	282.	188.	141.	94.	70.5	56.4
70	.....	.....	.....	.....	327.	218.	163.	109.	81.5	65.4

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INERTIA OF TRAINS.—II.

S Speed Miles per Hour, to be Attained in given Time.	Tractive Force, Pounds per Ton (2000 Pounds) to Attain Speed S, in Time t from Starting = $1.52\frac{S}{t}$									
	½ Minute.	1 Minute.	1½ Minute.	2 Minutes.	3 Minutes.	4 Minutes.	5 Minutes.	6 Minutes.	8 Minutes.	10 Minutes.
4	12.16	6.08	4.08	3.04	2.02	1.52	1.21	1.01	.76	.60
5	15.2	7.6	5.06	3.8	2.53	1.9	1.52	1.26	.95	.76
6	18.24	9.12	6.12	4.56	3.03	2.28	1.81	1.51	1.14	.9
6	24.32	12.16	8.16	6.08	4.04	3.04	2.42	2.02	1.52	1.2
10	30.4	15.2	10.12	7.6	5.06	3.8	3.04	2.52	1.9	1.52
12	36.48	18.24	12.24	9.12	6.06	4.56	3.63	3.03	2.28	1.82
15	45.6	22.8	15.2	10.1	7.6	5.7	4.6	3.8	2.85	2.28
20	60.8	30.4	20.24	15.2	10.12	7.6	6.08	5.04	3.8	3.04
25	76.	38.	25.3	19.	12.65	9.5	7.6	6.3	4.75	3.8
30	91.2	45.6	30.4	20.2	15.2	11.4	9.2	7.6	5.7	4.56
35	106.	53.2	35.4	24.	17.7	13.3	10.7	6.86	6.65	5.32
40	121.	60.8	40.8	30.4	20.2	15.2	12.16	10.08	7.6	6.08
45	136.	68.4	45.8	34.2	22.7	17.1	13.68	11.34	8.55	6.84
50	152.	76.	50.6	38.	25.3	19.	15.2	12.6	9.5	7.6
55	167.	83.6	55.6	41.8	27.8	20.9	16.7	13.86	10.45	8.36
60	182.	91.	60.	40.	30.	23.	18.4	15.2	11.4	9.12
65	197.	98.6	65.	44.	32.5	25.	20.	16.4	12.4	10.
70	212.	106.	70.	47.8	35.	26.9	21.28	17.66	13.35	10.7

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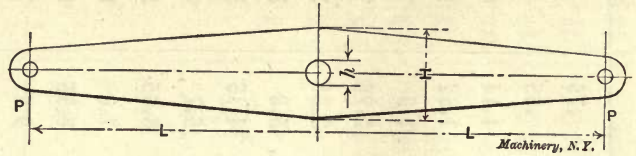
TABLE GIVING WIDTH H OF BRAKE LEVERS 3-4 INCH THICK CORRESPONDING TO THE MAXIMUM MOMENT Mx.

$Mx = PL$



$$H = \sqrt{\frac{Mx}{C}} + \frac{1''}{4}$$

$C = 3000$

Allowance made for Hole h under 1 1-4 in. diameter. Stress in outer Fiber varies from 20,000 to 23,000 lbs. per sq. in.

Mx	H	Mx	H	Mx	H
	Inches.		Inches.		Inches
6000	1 3/4	60000	4 3/4	150000	7 1/4
7500	1 7/8	63000	4 7/8	156000	7 1/2
9000	2	66000	4 7/8	162000	7 5/8
10500	2 1/8	69000	5	168000	7 3/4
12000	2 1/4	72000	5 1/8	174000	7 7/8
13500	2 3/8	75000	5 1/4	180000	8
15000	2 1/2	78000	5 3/8	186000	8 1/8
16500	2 5/8	81000	5 3/8	192000	8 1/4
18000	2 3/4	84000	5 1/2	198000	8 3/8
19500	2 3/4	87000	5 5/8	204000	8 1/2
21000	2 7/8	90000	5 3/4	210000	8 5/8
22500	3	93000	5 7/8	216000	8 3/4
24000	3 1/8	96000	5 7/8	222000	8 7/8
25500	3 1/8	99000	6	228000	9
27000	3 1/4	102000	6 1/8	234000	9 1/8
28500	3 1/2	105000	6 1/4	240000	9 1/4
30000	3 1/2	108000	6 1/4	246000	9 1/4
33000	3 5/8	111000	6 3/8	252000	9 3/8
36000	3 3/4	114000	6 3/8	258000	9 1/2
39000	3 7/8	117000	6 1/2	264000	9 5/8
42000	4	120000	6 5/8	270000	9 3/4
45000	4 1/8	123000	6 3/4	276000	9 7/8
48000	4 1/4	126000	6 3/4	282000	10
51000	4 3/8	132000	6 7/8	288000	10 1/8
54000	4 1/2	138000	7	294000	10 1/4
57000	4 5/8	144000	7 1/8	300000	10 1/4

TABLE GIVING WIDTH H OF BRAKE LEVERS 1 INCH THICK CORRESPONDING TO THE MAXIMUM MOMENT Mx. C = 4000.

Allowance made for Hole h under 1 1-2 in. diameter. Stress in outer Fiber varies from 20,000 to 23,000 lbs. per sq. in.

12000	2	24000	2 3/4	36000	3 1/4
14000	2 1/8	26000	2 3/4	38000	3 3/8
16000	2 1/4	28000	2 7/8	40000	3 1/2
18000	2 3/8	30000	3	44000	3 5/8
20000	2 1/2	32000	3 1/8	48000	3 3/4
22000	2 5/8	34000	3 1/4	52000	3 7/8

Contributed by E. G. Chenoweth, MACHINERY'S Data Sheet No. 33 (Railway Edition). Explanatory note: Page 39.

TABLE GIVING WIDTH H OF BRAKE LEVERS 1 INCH THICK CORRESPONDING TO THE MAXIMUM MOMENT Mx. (Continued.)

Allowance made for hole h under 1 1-2 in. diameter. Stress in outer Fiber varies from 20,000 to 23,000 lbs. per sq. in.

Mx	H	Mx	H	Mx	H
	inches.		Inches.		Inches.
56000	4	136000	6 1/8	224000	7 3/4
60000	4 1/8	140000	6 1/4	232000	7 7/8
64000	4 1/4	144000	6 1/4	240000	8
68000	4 3/8	148000	6 3/8	248000	8 1/8
72000	4 1/2	152000	6 3/8	256000	8 1/4
76000	4 5/8	156000	6 1/2	264000	8 3/8
80000	4 3/4	160000	6 5/8	272000	8 1/2
84000	4 7/8	164000	6 3/4	280000	8 5/8
88000	5	168000	6 3/4	288000	8 3/4
92000	5 1/8	172000	6 7/8	296000	8 7/8
96000	5 1/4	176000	6 7/8	304000	9
100000	5 1/4	180000	7	312000	9 1/8
104000	5 3/8	184000	7	320000	9 1/4
108000	5 1/2	188000	7 1/8	328000	9 3/8
112000	5 5/8	192000	7 1/4	336000	9 1/2
116000	5 3/4	196000	7 1/4	344000	9 5/8
120000	5 3/4	200000	7 3/8	352000	9 3/4
124000	5 7/8	208000	7 1/2	360000	9 7/8
128000	5 7/8	216000	7 5/8	368000	10
132000	6	.....	..	.....	...

TABLE GIVING WIDTH H OF BRAKE LEVERS 1 1-4 INCH THICK CORRESPONDING TO THE MAXIMUM MOMENT Mx. C = 5000.

Allowance made for Hole h under 1 1-2 in. diameter. Stress in outer Fiber varies from 20,000 to 23,000 lbs. per sq. in.

50000	3 1/8	140000	5 1/2	260000	7 1/2
55000	3 5/8	145000	5 5/8	270000	7 5/8
60000	3 3/4	150000	5 3/4	280000	7 3/4
65000	3 7/8	155000	5 3/4	290000	7 7/8
70000	4	160000	5 7/8	300000	8
75000	4 1/8	165000	6	310000	8 1/8
80000	4 1/4	170000	6 1/8	320000	8 1/4
85000	4 3/8	175000	6 1/4	330000	8 3/8
90000	4 1/2	180000	6 1/4	340000	8 1/2
95000	4 5/8	185000	6 3/8	350000	8 5/8
100000	4 3/4	190000	6 5/8	360000	8 3/4
105000	4 3/4	195000	6 1/2	370000	8 7/8
110000	4 7/8	200000	6 5/8	380000	9
115000	5	210000	6 3/4	390000	9 1/8
120000	5 1/8	220000	6 7/8	400000	9 1/4
125000	5 1/4	230000	7	410000	9 3/8
130000	5 3/8	240000	7 1/4	420000	9 3/8
135000	5 1/2	250000	7 3/8	430000	9 1/2

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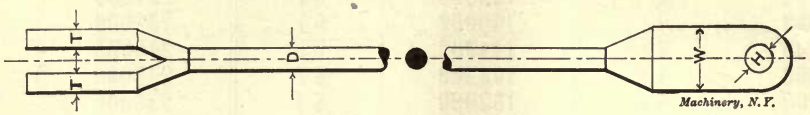
PROPORTIONS FOR BRAKE RODS.

Based on M. C. B. Recommended Practice.

Fiber Stress for Diameter D not to exceed 15,000 pounds per square inch.
" " " Width W " " " 10,000 " " " "
Shear on Pins H not to exceed 10,000 pounds per square inch.



Machinery, N.Y.

Diam. of Rod D.	Area of Section D	Strength of Rod, Fiber Stress 15,000 pounds per square inch.	Sectional Area of Jaw through Pin-Hole; Fiber Stress 10,000 lbs. per square inch.	Diameter of Pin Hole H for Various Diameters of D.	Square of Diameter of Pin-hole H.	Width W for Various Thicknesses of T. (Given to the Nearest 1/8".)					
						5/8"	3/4"	7/8"	1"	1 1/8	1 1/4"
7/8"	.6013	9020	.9020	1 1/8"	1.2656	1 7/8"	1 3/4"	1 5/8"	1 5/8"	....	....
1"	.7854	11781	1.1781	1 1/8"	1.2656	2"	2"	1 7/8"	1 3/4"	....	....
1 1/8"	.9940	14910	1.4910	1 1/8"	1.2656	2 3/8"	2 1/8"	2"	2"	1 3/4"	....
1 1/4"	1.2272	18408	1.8408	1 1/8"	1.2656	2 5/8"	2 3/8"	2 1/8"	2 1/8"	2"	....
1 3/8"	1.4849	22274	2.2274	1 1/4"	1.5625	3 1/8"	2 3/4"	2 1/2"	2 3/8"	2 1/4"	2 1/8"
1 1/2"	1.7671	26507	2.6507	1 3/8"	1.8906	3 1/2"	3 1/8"	2 7/8"	2 3/4"	2 1/2"	2 1/2"
1 5/8"	2.0739	31109	3.1109	1 1/2"	2.2500	4"	3 5/8"	3 1/4"	3"	2 7/8"	2 3/4"
1 3/4"	2.4053	36080	3.6080	1 5/8"	2.6406	4 1/2"	4"	3 5/8"	3 1/2"	3 1/4"	3 1/8"
1 7/8"	2.7612	41418	4.1418	1 5/8"	2.6406	....	4 3/8"	4"	3 3/4"	3 1/2"	3 1/4"
2"	3.1416	47124	4.7124	1 3/4"	3.0625	....	5"	4 1/2"	4 1/8"	3 7/8"	3 5/8"
2 1/8"	3.5466	53199	5.3199	1 7/8"	3.5156	....	....	5"	4 1/2"	4 1/4"	4"
2 1/4"	3.9761	59642	5.9642	2"	4.0000	....	....	5 1/2"	5"	4 5/8"	4 3/8"
2 3/8"	4.4301	66452	6.6452	2 1/8"	4.5156	....	....	....	5 1/2"	5"	4 3/4"
2 1/2"	4.9087	73631	7.3631	2 1/4"	5.0625	....	....	....	6"	5 1/2"	5 1/4"
2 5/8"	5.4119	81179	8.1179	2 3/8"	5.6406	....	....	....	6 1/2"	6"	5 5/8"
2 3/4"	5.9396	89094	8.9094	2 1/2"	6.2500	....	....	....	....	6 1/2"	6 1/8"
2 7/8"	6.4918	97377	9.7377	2 1/2"	6.2500	....	....	....	....	....	6 1/2"
3"	7.0686	106029	10.6029	2 5/8"	6.8906	....	....	....	....	....	6 7/8"
3 1/8"	7.6699	115049	11.5049	2 3/4"	7.5625	....	....	....	....	....	7 3/8"

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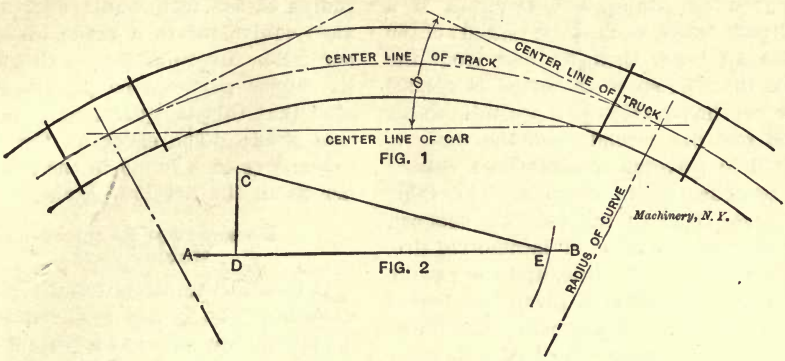
ANGLES OF DEFLECTION OF CENTER LINE OF TRUCK FROM CENTER LINE OF CAR ON CURVES.



Put $\sin \phi = \frac{\frac{1}{2} L}{R}$, in which L = length center to center of bolsters and R = radius of curve, in feet, and the angle ϕ can be laid out without using protractor. Erect to scale a perpendicular $C D = \frac{1}{2} L$ on base line $A B$, Fig. 2. Then with C as a center, and radius R = radius of curve, to same scale, strike an arc intersecting $A B$ at E. Angle $C E D$ is the angle required.

RADIUS OF CURVE IN FEET.

Center to Center of Bolsters, in feet.	50	60	70	80	90	100	110	120	130	140	150	160	170
10	5° 45′	4° 47′	4° 6′	3° 38′	3° 11′	2° 52′	2° 36′	2° 23′	2° 12′	2° 3′	1° 54′	1° 50′	1° 41′
11	6 19	5 11	4 30	3 57	3 30	3 9	2 52	2 38	2 28	2 15	2 6	1 58	1 51
12	6 54	5 45	4 55	4 19	3 47	3 27	3 7	2 52	2 39	2 27	2 18	2 9	2 1
13	7 28	6 15	5 20	4 40	4 9	3 44	3 26	3 6	2 52	2 40	2 29	2 20	2 12
14	8 3	6 30	5 45	5 1	4 28	4 1	3 39	3 21	3 5	2 52	2 40	2 31	2 22
15	8 38	7 11	6 9	5 23	4 47	4 19	3 54	3 35	3 18	3 4	2 52	2 41	2 32
16	9 13	7 39	6 34	5 45	5 6	4 36	4 10	3 49	3 32	3 17	3 3	2 52	2 41
17	9 47	8 9	6 59	6 6	5 25	4 53	4 26	4 4	3 45	3 29	3 15	3 3	2 52
18	10 22	8 38	7 23	6 28	5 45	5 10	4 42	4 18	3 58	3 41	3 27	3 13	3 2
19	10 57	9 7	7 43	6 49	6 4	5 27	4 57	4 32	4 11	3 53	3 38	3 24	3 12
20	11 32	9 36	8 13	7 11	6 23	5 45	5 13	4 47	4 25	4 5	3 49	3 35	3 22
21	11 36	10 5	8 38	7 33	6 42	6 2	5 29	5 1	4 38	4 18	4 1	3 46	3 32
22	12 43	10 34	9 3	7 54	7 1	6 19	5 45	5 15	4 51	4 30	4 12	3 57	3 43
23	13 18	11 3	9 27	8 16	7 20	6 36	6 0	5 30	5 4	4 43	4 24	4 7	3 53
24	13 53	11 32	9 52	8 38	7 40	6 54	6 16	5 45	5 18	4 55	4 35	4 18	4 3
25	14 29	12 1	10 17	8 59	7 59	7 11	6 32	5 59	5 31	5 7	4 47	4 29	4 13
26	15 4	12 31	10 42	9 21	8 18	7 28	6 47	6 13	5 45	5 20	4 58	4 40	4 23
27	15 40	13 0	11 7	9 43	8 38	7 46	7 3	6 28	5 58	5 32	5 10	4 50	4 33
28	16 16	13 30	11 32	10 5	8 57	8 3	7 19	6 42	6 11	5 45	5 21	5 1	4 43
29	16 52	13 59	11 57	10 27	9 16	8 20	7 35	6 56	6 24	5 51	5 33	5 12	4 53
30	17 28	14 29	12 22	10 49	9 36	8 38	7 50	7 11	6 37	6 9	5 45	5 23	5 4
31	18 4	14 58	12 48	11 10	9 55	8 55	8 6	7 25	6 51	6 21	5 56	5 33	5 14
32	18 40	15 28	13 13	11 32	10 14	9 13	8 22	7 40	7 4	6 34	6 7	5 45	5 24
33	19 17	15 58	13 38	11 54	10 42	9 30	8 38	7 54	7 18	6 46	6 19	5 55	5 34
34	19 53	16 28	14 4	12 16	10 53	9 47	8 53	8 9	7 31	6 59	6 20	6 6	5 45
35	20 29	16 57	14 29	12 38	11 13	10 5	9 9	8 23	7 31	7 11	6 42	6 17	5 55
36	21 6	17 28	14 54	13 0	11 32	10 23	9 25	8 38	7 57	7 23	6 54	6 28	6 5

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of trains. In the table on page 26 a comparison is made between speed in miles per hour, feet per hour, feet per minute, feet per second, and the time required per mile. For example, if a railroad train runs at a speed of 50 miles an hour, then we find from the table that the space traversed is 264,000 feet per hour, 4400 feet per minute, or 73.33 feet per second; and the time required to traverse one mile is 1 minute 12 seconds, or 72 seconds. The table on page 27 gives the relation between the diameter of a car or locomotive tire, the revolutions per mile, and the revolutions per minute at a given number of miles per hour. Assume that the diameter of the driving wheel of a locomotive is 56 inches. Then we find from the table that its circumference is 14.66 feet, and that it makes 360.2 revolutions per mile. If the locomotive runs at a speed of 40 miles per hour, it will be seen that the driving wheel will make 240.12 revolutions per minute.

Grades and their Effect on Hauling Capacity

On page 28 a table is given of the relation between grades and the hauling capacity of locomotives. From the table it will be seen that a three per cent grade, for example, is equivalent to a rise of 158.4 feet per mile, or a rise of 1 foot in 33.33 feet. At a speed of 10 miles per hour, the resistance per each ton hauled is equivalent to 69.9 pounds. Assuming that the tractive power of a locomotive is one-fourth of the weight on the drivers, the number of tons hauled on a three per cent grade, for each 1000 pounds on the drivers, would be 3.8. Assuming that the tractive power is only one-fifth of the weight on the drivers, this giving a more conservative calculation, only three tons can be hauled for each 1000 pounds on the drivers.

In the lower part on page 28 a table is given where curves are reduced to equivalent grade, so as to make it possible to use the table in the upper part of the page to find the hauling capacity of locomotives on curves. For example, a 20-degree curve, or a curve having a radius of 288 feet, would offer a resistance equivalent to a grade of 26.4 feet per mile. By referring to the table in the upper part of the page it will be seen that this is equivalent to a 0.5 per cent grade. The effect on the hauling capacity is then found in the same manner as in the previous example.

Horsepower Required for Moving Cars

It is a rather complicated problem to determine the power required to move a railroad car of known weight at any known speed over a level track, or up a known grade. A diagram, or graphical chart, however, can be prepared, from which the power required may be obtained practically at a glance if the quantities speed, weight and grade be known. Such a diagram is presented on page 29. Suppose, for an example, that the car weighs 15 tons, or 30,000 pounds, and assume further that we wish to move this car at a speed of 25 miles per hour over a level track. Find first on the right-hand vertical scale the point marked 15 tons (the weight of the car), and follow the horizontal line from this point to the intersection with the oblique line marked 25 miles per hour and from this intersection follow a vertical line downward intersecting the horsepower scale for level track at 30½ H.P. Suppose that the car must also climb a grade of 3 per cent somewhere on the line. In order to find the horsepower required for this, follow the same vertical line, already found, until it intersects the oblique grade line marked 3 per cent grade, and then follow the horizontal line from this intersection point to the right-hand vertical scale, where we find the required power for climbing the grade to be 93 H.P. As will be seen, the diagram can be used for cars weighing up to 20 tons, for

speeds from 3 to 30 miles per hour, and for grades from 1 to 10 per cent.

Constants for Calculating Tractive Force

On pages 30 and 31 are given tables containing constants for the calculation of the tractive force of locomotives. The note beneath the upper table on page 30 gives the necessary explanation of the tables and illustrates their use by means of an example.

Inertia of Trains

On pages 32 and 33 are given two tables of the inertia of trains. These tables give the tractive force, in pounds, required for each ton hauled to obtain a speed of S miles per hour, in a certain distance in feet. As an example, find the tractive force required per each ton of load hauled to attain a speed of 10 miles per hour in a distance of 1000 feet. By referring to the table on page 32, we find that the tractive force required is 6.68 pounds per ton.

The table on page 33 gives the tractive force, in pounds, which is required per ton of load for attaining a speed of S miles per hour in a specified length of time. As an example, find the tractive force required for attaining a speed of 30 miles per hour in three minutes. By referring to the table on page 33 we find that a tractive force of 15.2 pounds per ton hauled is required.

Brake Levers

On pages 34 and 35 is given a table of the width of brake levers in which the maximum fiber stress does not exceed the recommended figure of 23,000 pounds per square inch adopted by the Master Car Builders' Association.

The formula

$$H = \sqrt{\frac{Mx}{C}} + 1/4 \text{ inch}$$

is derived as follows:

Let Mx = maximum moment,
S = stress per square inch,
I = moment of inertia,
E = maximum distance from the center of gravity to outer fiber = $H/2$,
H = width of lever,
b = thickness of lever,
h = diameter of hole,
C = constant which varies with b,
P = pull at end of lever,
L = lever arm.

Then for a lever 1 inch thick:

$$PL = Mx = \frac{SI}{E} = \frac{24{,}000\, b H^2}{12\, E} =$$

$$\frac{2000\, b H^2}{E} = \frac{2000\, H^2}{H/2} = 4000\, H^2$$

Hence, $H^2 = \frac{Mx}{4000}$, and $H = \sqrt{\frac{Mx}{4000}}$.

For other levers the formulas are derived in the same way, the value of b only being changed. By taking 24,000 pounds for the value of S and then adding 1/4 inch to the width, the maximum allowable stresses vary from 20,000 to 23,000 pounds per square inch, as given in the tables. For a ¾-inch thick brake lever, $C = 3000$ instead of 4000.

On page 36 are given proportions for brake rods according to the Master Car Builders' recommendations.

Deflection of Truck from Center of Car on Curves

On page 37 are given angles of deflection of the center line of the truck from the center line of the car on curves, for various radii. For example, if the center to center distance of the bolsters is 25 feet, and the radius of the curve 150 feet, then, according to the table, the angle of deflection of the center line of the truck from the center line of the car equals 4 degrees 47 minutes. These angles of deflection must be taken into consideration by the designer when laying out brake rigging connections, otherwise interference of the brake rods with the wheels is likely to develop on sharp curves.

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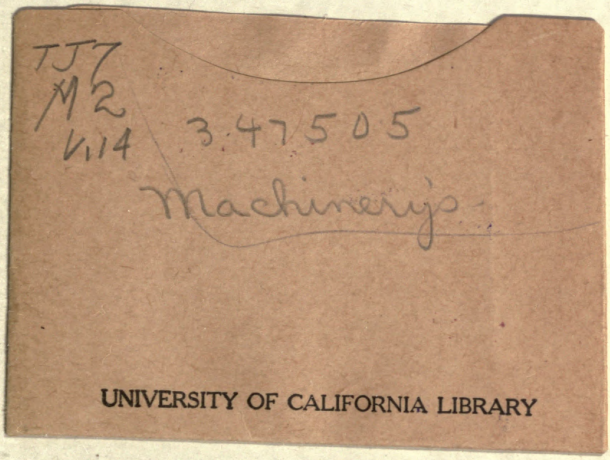
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